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E. J. STONE, Esq., M.A., F.R.S., President, in the Chair.

Henry George Hollingworth, Esq., F.R.G.S., 319 Vauxhall Bridge Road, S.W.;

Samuel Okell, Esq., Bowden, near Manchester;

William Barrett Roué, Esq., M.B., 165 Whiteladies Road, Clifton, Bristol; and

Hesketh Goddard Williamson, Esq., Shrigley Road, Bollington, near Macclesfield,

were balloted for and duly elected Fellows of the Society.

Discussion of the Observations of γ Draconis, made with the Greenwich Reflex Zenith Tube during the years 1857 *to* 1875 *inclusive.* By A. M. W. Downing, Esq., M.A.

In the twenty-ninth volume of the *Memoirs* of this Society there is a paper by Mr. Main containing a discussion of the observations made with the Reflex Zenith Tube during the eight years 1852-1859. The results of this discussion were not altogether satisfactory. The value of the constant of aberration which was deduced was $20''{\cdot}335$, or more than a tenth of a second smaller than Struve's value, which has been universally received by astronomers with such great confidence. Whilst the annual parallax of γ *Draconis* resulting from the observations was $-0''{\cdot}242$, a quantity too large to allow us to consider it accidental, and which probably indicated (the author considered) the existence of some periodic error, whether arising from the

instrument or from some deformation of the atmosphere, which affects the observations.

As the Reflex Zenith Tube has been in continuous use up to the present time (with the exception of some interruption during the years 1871 and 1872, when the experiments with the Water Telescope were in progress), I have felt that it was desirable that another attempt should be made to utilise the observations for a determination of the constant of aberration; and, as it seemed unlikely, owing to the discouraging circumstances mentioned above, that any person not connected with the Greenwich Observatory would undertake such a laborious task, I have myself entered on the investigation, the results of which I have now the honour to present to the Society.

I have begun my investigation with the year 1857, as previously to that date the instrument was located in a different and (apparently) most unsatisfactory position, and the mercury trough was supported in a different manner to that finally adopted, so that the star's image was subject to great unsteadiness, and it was, I believe, impossible to take an observation in the daytime. It appeared to me, therefore, that it would be better to begin my discussion from the time when the instrument was brought into its present position, and the suspension of the mercury trough arranged in the manner which has remained unaltered up to the present time. And I have concluded my investigation with the year 1875, thus embracing the period of a complete revolution of the Moon's Node, so that a value of the constant of nutation may also be determined from these observations, and the number of observations made during this interval of time being very great, it seemed probable that as good a value of the constant of aberration could be obtained from this series as the instrument was capable of giving even from a longer term of years.

The observations of apparent zenith distance have been extracted from the volumes of Greenwich Observations for the different years, those observations only being used which were made in both positions of the instrument. The observations were then combined in convenient groups, each group not extending over more than twelve or, at the most, fourteen days, it being assumed that the mean of the observed Z. D.'s corresponds to the mean of the times of observation. We have thus a series of observed apparent zenith distances, which are to be compared with the assumed mean zenith distance by the application (to the latter) of corrections for precession and proper motion, aberration, annual parallax, and nutation.

The assumed mean Z. D. North is $102''{\cdot}37+w$ for the epoch 1866·0.

The precession for this epoch applicable to mean Z. D. North of γ *Draconis* is $-0''{\cdot}569$, and the assumed proper motion in Z. D. North is $-(0''{\cdot}028+\delta p)$; so that the annual variation for 1866 is $-(0''{\cdot}597+\delta p)$. If the mean Z. D. North for 1866·0

be assumed to be 102″·37, the following are the corresponding values for the different years:—

Date.	Mean Z. D. North.	Date.	Mean Z. D. North.
1857·0	107″·83	1867·0	101″·78
58·0	107·21	68·0	101·18
59·0	106·60	69·0	100·59
60·0	105·99	70·0	100·00
61·0	105·38	71·0	99·41
62·0	104·78	72·0	98·83
63·0	104·17	73·0	98·24
64·0	103·57	74·0	97·66
65·0	102·97	1875·0	97·08
1866·0	102·37		

And the correction for annual variation applicable at any date is the annual variation for the year multiplied by the fraction of the year counted from the instant when the Sun's mean longitude is 280°.

The assumed value of the constant of aberration is $20''\cdot4+x$, and therefore the correction applicable to mean Z. D. North is generally

$$-(20''\cdot4+x)\{\cos\alpha\cos\Delta\sin\odot+(\sin\omega\sin\Delta-\cos\omega\sin\alpha\cos\Delta)\cos\odot\}.$$

Assuming that, in the case of *γ Draconis*, for 1860,

$$\alpha=268^\circ\,20'\,15'',\qquad \Delta=38^\circ\,29'\,36'',\qquad \omega=23^\circ\,27'\,27'',$$

and for 1870

$$\alpha=268^\circ\,23'\,45'',\qquad \Delta=38^\circ\,29'\,42'',\qquad \omega=23^\circ\,27'\,22'',$$

the above expression becomes, for 1860,

$$-\cdot96580\cos(1^\circ\,21'+\odot)\times(20''\cdot4+x),$$

and for 1870,

$$-\cdot96574\cos(1^\circ\,18'+\odot)\times(20''\cdot4+x).$$

From these formulæ it is easy to find the correction for any epoch between 1857 and 1875 corresponding to any value of ⊙, and it evidently consists of two parts—a numerical correction to the assumed mean Z. D. North, corresponding to the value 20″·4 of the constant of aberration, and the correction x to that value multiplied by a numerical coefficient.

If y be the assumed value of the annual parallax of *γ Draconis*,

the corresponding correction to the assumed mean Z. D. North is found immediately from the above expressions to be, for 1860,

$$+\cdot 96580\ \mathrm{R}\sin(1^\circ\ 21' + \odot) \times y,$$

and for 1870,

$$+\cdot 96574\ \mathrm{R}\sin(1^\circ\ 18' + \odot) \times y,$$

where R is the Earth's radius vector.

The expression for nutation is taken from Peters' *Numerus Constans Nutationis*, p. 74, omitting terms which are quite insensible in the case of γ *Draconis*. Assuming the constant to be, for 1866,

$$9''\cdot 2237\left(1 + \frac{z}{10}\right),$$

the correction applicable to mean Z. D. North is, for 1860,

$$\left(1+\frac{z}{10}\right)\left\{\begin{array}{l} -6''\cdot 8669\cos\alpha\sin\Omega + 9''\cdot 2236\sin\alpha\cos\Omega + 0''\cdot 0822\cos\alpha\sin 2\Omega \\ \quad\cdot 8672 \qquad\qquad\qquad\quad \cdot 2237 \\ -0''\cdot 0896\sin\alpha\cos 2\Omega - 0''\cdot 0813\cos\alpha\sin 2\mathbb{C} + 0''\cdot 0886\sin\alpha\cos 2\mathbb{C} \end{array}\right\}$$

$$+\left(1 - 2\cdot 162 \times \frac{z}{10}\right)\left\{-0''\cdot 5053\cos\alpha\sin 2\odot + 0''\cdot 5508\sin\alpha\cos 2\odot\right\}$$

where the figures below the line are the corresponding values of the coefficients for 1870. For γ *Draconis* this expression is easily reduced to the following:—

$$\left(1+\frac{z}{10}\right)\left\{\begin{array}{l} -9''\cdot 2219\cos(\Omega + 1^\circ\ 14') + 0''\cdot 090\cos(2\Omega + 1^\circ\ 32') \\ \quad\cdot 2221 \qquad\qquad\quad 12 \qquad\qquad\qquad\quad 29 \\ -0''\cdot 089\cos(2\mathbb{C} + 1^\circ\ 32') \\ \qquad\qquad\qquad\quad 29 \end{array}\right\}$$

$$-\left(1+\frac{z}{10} - 0''\cdot 316\,z\right) \times 0''\cdot 551\cos(2\odot + 1^\circ\ \underset{28}{31'}),$$

where the figures on the line are the values for 1860, those below the line the corresponding values for 1870. From this expression has been found the correction applicable to the assumed mean Z. D. North, at the mean date of each normal group, and it evidently, like the correction for aberration, consists of a numerical correction, corresponding to the value of the constant $9''\cdot 2237$, and the correction z multiplied by a numerical coefficient. The values of $\odot$, $\mathbb{C}$ and Ω have been taken from the *Nautical Almanacs* of the different years.

In this manner have been formed the equations of condition, corresponding to each normal group of observed Z. D.'s, the equations containing the five unknown quantities—w, x, y, z, and δp. I have not attempted to determine the value of δp, but merely exhibit its effect on the values of the other quantities.

From the 1,044 observations made during the period under

consideration, I have formed 266 equations of condition as is shown in the following tabular statement.

Means of Observed Z. D.'s of γ Draconis from Groups.

No.	Extent of Group.	Mean Day and Hour.	Mean of Observed Z. D.'s.	No. of Obs.
		d h	"	
1	1857, Jan. 1	Jan. 1·23	94·67	1
2	Feb. 9–16	Feb. 13 6	82·35	5
3	Mar. 12–17	Mar. 15 18	78·46	4
4	April 14–20	Apr. 17 12	80·86	6
5	29–May 14	May 7 11	85·36	7
6	May 25–June 8	31 10	92·47	6
7	June 10–18	June 14 6	97·08	7
8	23–30	26 8	100·43	6
9	July 7–18	July 12 21	106·00	9
10	20–Aug. 5	27 10	110·01	8
11	Aug. 12–27	Aug. 21 5	115·11	8
12	Sept. 3–9	Sept. 6 2	116·57	5
13	16–Oct. 1	23 18	117·88	8
14	Oct. 5–14	Oct. 8 13	116·91	3
15	26–30	28 3	114·60	3
16	Nov. 11	Nov. 11 3	111·14	1
17	27–Dec. 4	29 17	105·76	3
18	Dec. 10–11	Dec. 10 13	102·24	2
19	31	31 23	95·63	1
20	1858, Jan. 6–13	Jan. 10 23	91·71	3
21	25–31	28 4	86·42	4
22	Feb. 18–25	Feb. 22 12	80·12	6
23	Mar. 8–10	Mar. 9 19	78·59	3
24	21–26	23 18	78·67	4
25	April 13–21	Apr. 18 10	80·34	4
26	May 4–13	May 8 11	85·35	7
27	18–29	22 19	89·06	5
28	June 3–19	June 13 2	95·79	11
29	22–July 8	29 8	101·52	6
30	July 12–21	July 16 10	106·68	7
31	26–Aug. 7	Aug. 1 22	110·82	9
32	Aug. 10–19	13 8	113·07	5
33	26–Sept. 8	31 7	116·14	5
34	Sept. 13–24	Sept. 17 9	117·34	8
35	Oct. 5–12	Oct. 7 21	116·89	3

No.	Extent of Group.	Mean Day and Hour.	Mean of Observed Z. D.'s.	No. of Obs.
		d h	"	
36	1858, Oct. 30–Nov. 11	Nov. 4 11	112·59	3
37	Nov. 18	Nov. 18 2	109·20	1
38	Dec. 1–3	Dec. 2 1	105·84	2
39	20–23	21 12	98·38	2
40	1859, Jan. 23–Feb. 6	Jan. 31 22	85·53	3
41	Feb. 17–27	Feb. 23 20	80·06	5
42	Mar. 7–18	Mar. 11 4	79·32	5
43	31–April 10	April 5 17	80·23	4
44	April 22	22 16	82·29	1
45	May 5–14	May 10 15	87·18	5
46	23–June 7	29 14	93·11	3
47	June 16–July 1	June 25 0	102·05	6
48	July 4–19	July 11 9	106·44	12
49	28–Aug. 5	Aug. 2 9	112·15	4
50	Aug. 16–26	21 18	115·36	7
51	30–Sept. 6	Sept. 2 13	117·55	4
52	Sept. 18–24	21 6	118·65	3
53	Oct. 3–14	Oct. 7 21	117·41	3
54	22–Nov. 3	27 20	114·74	3
55	Nov. 10–21	Nov. 16 20	110·75	4
56	23–Dec. 10	Dec. 1 1	106·55	5
57	Dec. 26	26 0	98·52	1
58	1860, Jan. 2–11	Jan. 7 11	94·18	2
59	22–23	23 10	89·40	2
60	Feb. 19–29	Feb. 25 0	81·36	6
61	Mar. 4–5	Mar. 5 7	80·96	2
62	14–21	17 18	80·40	4
63	April 1	April 1 17	80·35	1
64	May 9–24	May 19 22	91·83	6
65	June 4–6	June 5 13	96·58	3
66	13–20	16 18	99·83	4
67	July 4–14	July 10 18	107·65	3
68	20–21	20 22	110·20	2
69	30–Aug. 14	Aug. 7 4	114·48	5
70	Sept. 4–14	Sept. 10 6	119·57	5
71	26–Oct. 3	29 5	118·65	3
72	Oct. 9–22	Oct. 16 22	118·28	4
73	30–Nov. 9	Nov. 3 3	115·44	4

No.	Extent of Group.	Mean Day and Hour.	Mean of Observed Z. D.'s.	No. of Obs.
		d h	″	
74	1860, Nov. 20–23	Nov. 21 14	110·80	2
75	Dec. 19–28	Dec. 24 15	100·25	3
76	1861, Jan. 8–9	Jan. 9 10	94·90	2
77	Feb. 11–26	Feb. 20 20	83·75	3
78	Mar. 20–21	Mar. 21 6	81·61	2
79	May 16–22	May 19 4	93·47	5
80	June 8–19	June 14 12	101·45	7
81	22–27	25 0	104·48	4
82	July 5–16	July 11 10	109·12	5
83	23–Aug. 2	29 3	114·86	4
84	Aug. 6–15	Aug. 12 3	117·73	4
85	19–30	25 1	120·43	10
86	Sept. 3–10	Sept. 6 15	121·39	3
87	30–Oct. 8	Oct. 4 5	122·87	2
88	Oct. 23–Nov. 1	27 12	119·06	6
89	Dec. 2–11	Dec. 7 5	108·11	3
90	1862, Jan. 9	Jan. 9 22	96·66	1
91	Mar. 18	Mar. 18 18	84·69	1
92	April 15–24	April 20 4	85·81	2
93	May 20	May 20 14	95·84	1
94	June 3	June 3 13	99·74	1
95	25–30	28 0	108·22	2
96	July 12	July 12 13	113·08	1
97	19–28	23 20	116·77	5
98	Aug. 1–14	Aug. 6 14	119·20	5
99	19–Sept. 1	26 7	123·66	5
100	Sept. 10–19	Sept. 15 18	126·22	4
101	Oct. 1–16	Oct. 8 0	124·22	5
102	1863, Jan. 6	Jan. 6 23	101·54	1
103	30–Feb. 3	Feb. 1 21	92·97	2
104	Feb. 12–17	14 20	90·77	3
105	Mar. 2	Mar. 2 19	87·71	1
106	13	13 19	86·32	1
107	May 13	May 13 15	95·87	1
108	25–26	26 2	99·52	2
109	June 1–4	June 3 1	102·92	4
110	15–30	23 19	109·30	7
111	July 2–18	July 11 23	115·12	11

No.	Extent of Group.	Mean Day and Hour.	Mean of Observed Z. D.'s.	No. of Obs.
		d h	"	
112	1863, July 23–Aug. 1	28 17	119·74	6
113	Aug. 8–15	Aug. 12 4	122·22	5
114	17–24	20 8	124·50	4
115	Sept. 17–29	Sept. 23 9	127·73	7
116	Oct. 9–23	Oct. 16 12	125 98	3
117	Nov. 25–Dec. 4	Nov. 29 7	116·44	4
118	1864, Jan. 27–31	Jan. 29 13	95·98	3
119	Feb. 9	Feb. 9 20	96·42	1
120	Mar. 17–23	Mar. 19 10	89·72	3
121	May 13–23	May 18 8	100·35	4
122	30–June 7	June 4 7	105·36	4
123	June 10–16	13 13	108·07	3
124	30–July 5	July 2 17	115·36	4
125	July 14–23	18 20	119·38	5
126	29–Aug. 8	Aug. 4 3	123·44	4
127	Aug. 10–17	13 8	125·33	6
128	26–Sept. 10	Sept. 4 23	127·66	3
129	Sept. 22–28	25 6	129·17	6
130	Oct. 1–7	Oct. 4 5	128·93	2
131	20–Nov. 3	26 4	126·22	3
132	Nov. 25–Dec. 9	Dec. 2 6	116·85	5
133	1865, Jan. 12	Jan. 12 22	100·87	1
134	Feb. 19	Feb. 19 20	93·49	1
135	Mar. 19	Mar. 19 18	90·89	1
136	May 12	May 12 15	99·25	1
137	24–31	27 6	105·08	3
138	June 8–12	June 10 7	109·23	4
139	19–28	22 12	112·73	5
140	July 3–15	July 9 19	118·16	6
141	19–28	24 0	121·97	5
142	Aug. 1–11	Aug. 5 3	124·66	4
143	18–30	25 0	129·47	3
144	Sept. 2–8	Sept. 5 15	129·57	6
145	14–29	22 1	130·83	9
146	Oct. 2–12	Oct. 5 19	129·95	7
147	1866, Jan. 14–18	Jan. 16 22	102·77	2
148	Feb. 18–23	Feb. 21 8	94·33	2
149	Mar. 1–15	Mar. 6 19	91·92	4

No. 148. An observation taken on 1866, Feb. 13, has been rejected.

No.	Extent of Group.	Mean Day and Hour.	Mean of Observed Z. D.'s.	No. of Obs.
		d h	″	
150	1866, May 3–4	May 4 3	99·09	2
151	16–28	21 17	103·61	8
152	June 8	June 8 13	109·09	1
153	19–28	24 12	114·14	5
154	July 4–14	July 10 11	118·71	5
155	18–20	19 10	122·19	2
156	Aug. 3–9	Aug. 5 17	125·73	3
157	14–25	19 13	128·17	5
158	Sept. 10	Sept. 10 7	129·79	1
159	27	27 6	128·45	1
160	Oct. 8–16	Oct. 12 5	129·13	3
161	Oct. 26–31	28 16	127·81	2
162	Nov. 30	Nov. 30 3	119·60	1
163	1867, Feb. 6	Feb. 6 21	96·13	1
164	Mar. 15	Mar. 15 18	91·05	1
165	May 29–30	May 30 1	104·11	2
166	June 10–17	June 13 13	109·09	5
167	22–28	26 2	113·94	5
168	July 6–16	July 10 23	118·01	6
169	24–Aug. 2	29 18	122·49	3
170	Aug. 6–20	Aug. 13 12	126·44	7
171	24–Sept. 5	30 17	128·60	5
172	Sept. 16–Oct. 1	Sept. 23 10	130·55	6
173	Oct. 17	Oct. 17 4	129 66	1
174	Nov. 6	Nov. 6 3	125·77	1
175	1868, Feb. 5	Feb. 5 21	94·58	1
176	27	27 19	92·18	1
177	Mar. 5–19	Mar. 11 13	89·84	4
178	May 14–20	May 18 11	99·68	4
179	23–28	26 9	101·03	5
180	June 1–11	June 6 5	104·63	6
181	15–19	17 13	107·61	5
182	22–29	25 16	110·95	7
183	July 7–10	July 9 0	115·89	4
184	13–17	15 10	117·05	5
185	20–27	23 20	119·68	5
186	31–Aug. 12	Aug. 4 21	122·42	6
187	Sept. 1–11	Sept. 5 16	127·30	8
188	21–23	22 6	127·40	3

No.	Extent of Group.	Mean Day and Hour.	Mean of Observed Z. D.'s.	No. of Obs.
		d h	″	
189	1868, Oct. 7–12	Oct. 9 14	126·49	4
190	29	29 3	123·32	1
191	1869, Jan. 21–24	Jan. 23 10	95·62	2
192	Feb. 5–18	Feb. 12 9	90·75	2
193	Mar. 12	Mar. 12 19	86·30	1
194	April 1	April 1 18	86·24	1
195	29–May 12	May 5 15	92·70	2
196	May 20–31	27 5	100·27	3
197	June 3–18	June 11 6	104·32	7
198	25–28	26 20	109·56	3
199	July 10–24	July 18 3	115·18	7
200	27–Aug. 7	Aug. 3 3	119·38	4
201	Aug. 11–24	17 15	122·45	7
202	26–Sept. 3	29 2	124·69	4
203	Oct. 6–12	Oct. 9 5	124·17	2
204	Nov. 15–18	Nov. 16 14	115·65	2
205	Dec. 1	Dec. 1 1	114·54	1
206	1870, Jan. 12–27	Jan. 20 10	94·43	2
207	Feb. 24	Feb. 24 20	85·74	1
208	Mar. 13	Mar. 13 18	84·59	1
209	May 16–26	May 21 2	94·24	8
210	June 1–10	June 7 1	100·43	4
211	14–24	19 9	103·30	8
212	29–July 7	July 2 11	108·16	4
213	July 12–28	20 1	112·82	13
214	Aug. 6–19	Aug. 13 0	118·05	9
215	25–Sept. 8	Sept. 1 2	120·73	5
216	Sept. 21–Oct. 2	26 10	121·52	10
217	Oct. 10–11	Oct. 10 17	120·47	2
218	Nov. 1–2	Nov. 1 15	117·15	2
219	12	12 2	114·82	1
220	1871, Feb. 16	Feb. 16 20	84·92	1
221	May 22–26	May 24 14	92·57	3
222	June 5	June 5 12	95·70	1
223	July 4–8	July 6 11	105·29	4
224	15–19	17 18	109·12	3
225	29–Aug. 2	31 15	112·13	4
226	Aug. 7–15	Aug. 11 8	114·02	8
227	1872, Jan. 17–18	Jan. 18 10	88·47	2

No.	Extent of Group.	Mean Day and Hour.	Mean of Observed Z. D.'s.	No. of Obs.
		d h	″	
228	1872, Feb. 12	Feb. 12 21	81·61	1
229	Aug. 15	Aug. 15 8	112·03	1
230	Dec. 6	Dec. 6 1	100·21	1
231	25–28	27 15	91·50	3
232	1873, Jan. 26–27	Jan. 27 10	82·35	2
233	May 13–22	May 17 14	83·25	3
234	June 16–25	June 20 20	93·75	3
235	July 1	July 1 11	98·50	1
236	18–28	23 1	103·45	8
237	31-Aug. 9	Aug. 5 0	107·38	8
238	Aug. 13–26	18 14	108·60	8
239	30–Sept. 11	Sept. 5 23	109·68	3
240	Sept. 18–27	24 1	111·06	5
241	Oct. 17	Oct. 17 4	108·69	1
242	Nov. 15	Nov. 15 3	102·97	1
243	25	25 2	102·24	1
244	1874, May 15–29	May 22 9	80·59	5
245	June 1–13	June 8 0	85·52	9
246	22–24	23 12	89·98	2
247	July 1–7	July 4 7	94·28	6
248	13–23	17 13	98·03	8
249	28–30	29 9	101·63	3
250	Aug. 6–13	Aug. 9 9	103·51	4
251	17–21	19 8	105·87	4
252	28–Sept. 4	31 13	107·41	4
253	Sept. 10–15	Sept. 13 6	107·51	3
254	24–26	25 6	108·67	2
255	Oct. 8–12	Oct. 10 5	108·43	2
256	20–28	24 4	104·90	2
257	Nov. 20	Nov. 20 2	99·96	1
258	1875, May 20–24	May 22 14	79·73	3
259	31–June 1	June 1 1	81·92	2
260	June 8–19	14 22	86·08	5
261	22–26	24 12	90·88	3
262	July 1–12	July 7 5	95·49	4
263	26–Aug. 4	30 4	101·72	5
264	Aug. 14–25	Aug. 20 18	106·24	5
265	30–Sept. 9	Sept. 3 23	106·97	6
266	Sept. 14–25	17 16	108·07	5

Equations of Condition.

No.	Equations.	Weights.	Residuals.
1	$w-0\cdot224x-0\cdot924y-1\cdot010z+8\cdot995\delta p+0''\cdot05=0$	1	$+0''\cdot29$
2	$w-\cdot804-\cdot528-0\cdot863+8\cdot879-0\cdot28=0$	5	$-0\cdot06$
3	$w-\cdot965-\cdot051-\cdot783+8\cdot795+0\cdot02=0$	4	$+0\cdot19$
4	$w-\cdot843+\cdot473-\cdot840+8\cdot705+0\cdot24=0$	6	$+0\cdot33$
5	$w-\cdot638+\cdot733-0\cdot888+8\cdot651+0\cdot19=0$	7	$+0\cdot24$
6	$w-\cdot304+\cdot930-1\cdot014+8\cdot585+0\cdot14=0$	6	$+0\cdot14$
7	$w-\cdot086+\cdot977-1\cdot036+8\cdot547+0\cdot05=0$	7	$+0\cdot04$
8	$w+\cdot108+\cdot976-1\cdot035+8\cdot514+0\cdot65=0$	6	$+0\cdot63$
9	$w+\cdot365+\cdot908-1\cdot008+8\cdot461+0\cdot13=0$	9	$+0\cdot12$
10	$w+\cdot568+\cdot793-0\cdot958+8\cdot429+0\cdot06=0$	8	$+0\cdot06$
11	$w+\cdot835+\cdot490-\cdot865+8\cdot361-0\cdot11=0$	8	$-0\cdot06$
12	$w+\cdot934+\cdot248-\cdot818+8\cdot318+0\cdot21=0$	5	$+0\cdot29$
13	$w+\cdot965-\cdot042-\cdot787+8\cdot269-0\cdot42=0$	8	$-0\cdot29$
14	$w+\cdot924-\cdot282-\cdot803+8\cdot229-0\cdot21=0$	3	$-0\cdot05$
15	$w+\cdot776-\cdot570-\cdot880+8\cdot175-0\cdot79=0$	3	$-0\cdot60$
16	$w+\cdot613-\cdot738-\cdot940+8\cdot137-0\cdot42=0$	1	$-0\cdot21$
17	$w+\cdot341-\cdot891-0\cdot995+8\cdot086-0\cdot21=0$	3	$+0\cdot02$
18	$w+\cdot162-\cdot937-1\cdot026+8\cdot056-0\cdot32=0$	2	$-0\cdot09$
19	$w-\cdot204-\cdot928-1\cdot012+7\cdot998-1\cdot09=0$	1	$-0\cdot85$
20	$w-\cdot367-\cdot878-0\cdot985+7\cdot971-0\cdot60=0$	3	$-0\cdot36$
21	$w-\cdot619-\cdot730-\cdot922+7\cdot924-0\cdot76=0$	4	$-0\cdot53$
22	$w-\cdot879-\cdot397-\cdot815+7\cdot854-0\cdot18=0$	6	$+0\cdot03$
23	$w-\cdot953-\cdot153-\cdot778+7\cdot811-0\cdot36=0$	3	$-0\cdot18$
24	$w-\cdot963+\cdot079-\cdot773+7\cdot774-0\cdot69=0$	4	$-0\cdot54$
25	$w-\cdot837+\cdot483-820+7\cdot704+0\cdot50=0$	4	$+0\cdot59$
26	$w-\cdot629+\cdot740-\cdot910+7\cdot649-0\cdot06=0$	7	$-0\cdot02$
27	$w-\cdot436+\cdot874-\cdot960+7\cdot610+0\cdot41=0$	5	$+0\cdot42$
28	$w-\cdot108+\cdot974-\cdot988+7\cdot551+0\cdot75=0$	11	$+0\cdot74$
29	$w+\cdot151+\cdot970-\cdot990+7\cdot507+0\cdot26=0$	6	$-0\cdot25$
30	$w+\cdot414+\cdot887-\cdot956+7\cdot460+0\cdot21=0$	7	$+0\cdot20$
31	$w+\cdot635+\cdot739-\cdot888+7\cdot415+0\cdot38=0$	9	$+0\cdot40$
32	$w+\cdot762+\cdot601+\cdot844+7\cdot383+0\cdot47=0$	5	$+0\cdot51$
33	$w+\cdot904+\cdot343-\cdot765+7\cdot334+0\cdot17=0$	5	$+0\cdot25$
34	$w+\cdot964+\cdot069-\cdot730+7\cdot289+0\cdot07=0$	8	$+0\cdot18$
35	$w+\cdot928-\cdot267-\cdot750+7\cdot232-0\cdot21=0$	3	$-0\cdot05$
36	$w+\cdot699-\cdot660-\cdot834+7\cdot156-0\cdot10=0$	3	$+0\cdot11$
37	$w+\cdot521-\cdot803-\cdot888+7\cdot119-0\cdot09=0$	1	$+0\cdot14$

No.	Equations.	Weights.	Residuals.
38	$w + 0{\cdot}307x - 0{\cdot}902y - 0{\cdot}925z + 7{\cdot}081\delta p - 0''{\cdot}82 = 0$	2	$-0''{\cdot}59$
39	$w - {\cdot}021 - {\cdot}951 - {\cdot}935 + 7{\cdot}027 + 0{\cdot}20 = 0$	2	$+0{\cdot}45$
40	$w - {\cdot}664 - {\cdot}691 - {\cdot}811 + 6{\cdot}914 - 0{\cdot}49 = 0$	3	$-0{\cdot}24$
41	$w - {\cdot}886 - {\cdot}379 - {\cdot}713 + 6{\cdot}851 + 0{\cdot}08 = 0$	5	$+0{\cdot}30$
42	$w - {\cdot}956 - {\cdot}135 - {\cdot}670 + 6{\cdot}809 - 0{\cdot}71 = 0$	5	$-0{\cdot}52$
43	$w - {\cdot}922 + {\cdot}286 - {\cdot}679 + 6{\cdot}739 - 0{\cdot}86 = 0$	4	$-0{\cdot}72$
44	$w - {\cdot}802 + {\cdot}540 - {\cdot}716 + 6{\cdot}692 - 0{\cdot}11 = 0$	1	$-0{\cdot}01$
45	$w - {\cdot}605 + {\cdot}760 - {\cdot}795 + 6{\cdot}643 - 0{\cdot}76 = 0$	5	$-0{\cdot}72$
46	$w - {\cdot}339 + {\cdot}918 - {\cdot}846 + 6{\cdot}591 - 0{\cdot}85 = 0$	3	$-0{\cdot}83$
47	$w + {\cdot}079 + {\cdot}979 - {\cdot}868 + 6{\cdot}519 - 1{\cdot}09 = 0$	6	$-1{\cdot}09$
48	$w + {\cdot}335 + {\cdot}920 - {\cdot}820 + 6{\cdot}474 - 0{\cdot}17 = 0$	12	$-0{\cdot}16$
49	$w + {\cdot}638 + {\cdot}735 - {\cdot}751 + 6{\cdot}413 - 0{\cdot}15 = 0$	4	$-0{\cdot}11$
50	$w + {\cdot}835 + {\cdot}490 - {\cdot}652 + 6{\cdot}361 + 0{\cdot}54 = 0$	7	$+0{\cdot}61$
51	$w + {\cdot}915 + {\cdot}311 - {\cdot}612 + 6{\cdot}329 - 0{\cdot}17 = 0$	4	$-0{\cdot}07$
52	$w + {\cdot}966 + {\cdot}008 - {\cdot}574 + 6{\cdot}277 - 0{\cdot}27 = 0$	3	$-0{\cdot}16$
53	$w + {\cdot}933 - {\cdot}248 - {\cdot}591 + 6{\cdot}232 + 0{\cdot}32 = 0$	3	$+0{\cdot}43$
54	$w + {\cdot}784 - {\cdot}560 - {\cdot}633 + 6{\cdot}178 + 0{\cdot}43 = 0$	3	$+0{\cdot}64$
55	$w + {\cdot}542 - {\cdot}789 - {\cdot}711 + 6{\cdot}123 - 0{\cdot}13 = 0$	4	$+0{\cdot}11$
56	$w + {\cdot}327 - {\cdot}896 - {\cdot}755 + 6{\cdot}083 - 0{\cdot}08 = 0$	5	$+0{\cdot}17$
57	$w - {\cdot}094 - {\cdot}946 - {\cdot}758 + 6{\cdot}015 - 0{\cdot}31 = 0$	1	$-0{\cdot}04$
58	$w - {\cdot}303 - {\cdot}901 - {\cdot}726 + 5{\cdot}981 - 0{\cdot}22 = 0$	$1\frac{1}{2}$	$+0{\cdot}06$
59	$w - {\cdot}548 - {\cdot}782 - {\cdot}672 + 5{\cdot}937 - 0{\cdot}69 = 0$	2	$-0{\cdot}42$
60	$w - {\cdot}892 - {\cdot}365 - {\cdot}533 + 5{\cdot}848 - 0{\cdot}19 = 0$	6	$-0{\cdot}03$
61	$w - {\cdot}940 - {\cdot}219 - {\cdot}498 + 5{\cdot}823 - 0{\cdot}78 = 0$	2	$-0{\cdot}55$
62	$w - {\cdot}966 - {\cdot}013 - {\cdot}476 + 5{\cdot}789 - 0{\cdot}74 = 0$	4	$-0{\cdot}54$
63	$w - {\cdot}937 + {\cdot}234 - {\cdot}480 + 5{\cdot}748 + 0{\cdot}01 = 0$	1	$+0{\cdot}18$
64	$w - {\cdot}470 + {\cdot}854 - {\cdot}609 + 5{\cdot}616 - 0{\cdot}87 = 0$	6	$-0{\cdot}81$
65	$w - {\cdot}220 + {\cdot}955 - {\cdot}639 + 5{\cdot}571 - 0{\cdot}18 = 0$	3	$-0{\cdot}14$
66	$w - {\cdot}042 + {\cdot}980 - {\cdot}647 + 5{\cdot}539 + 0{\cdot}29 = 0$	4	$+0{\cdot}32$
67	$w + {\cdot}337 + {\cdot}921 - {\cdot}615 + 5{\cdot}474 + 0{\cdot}09 = 0$	3	$+0{\cdot}12$
68	$w + {\cdot}485 + {\cdot}847 - {\cdot}578 + 5{\cdot}445 + 0{\cdot}46 = 0$	2	$+0{\cdot}51$
69	$w + {\cdot}702 + {\cdot}671 - {\cdot}501 + 5{\cdot}399 + 0{\cdot}41 = 0$	5	$+0{\cdot}48$
70	$w + {\cdot}950 + {\cdot}176 - {\cdot}352 + 5{\cdot}306 + 0{\cdot}24 = 0$	5	$+0{\cdot}39$
71	$w + {\cdot}956 - {\cdot}136 - {\cdot}354 + 5{\cdot}254 + 1{\cdot}18 = 0$	3	$+1{\cdot}37$
72	$w + {\cdot}871 - {\cdot}416 - {\cdot}365 + 5{\cdot}205 + 0{\cdot}23 = 0$	4	$+0{\cdot}46$
73	$w + {\cdot}709 - {\cdot}650 - {\cdot}414 + 5{\cdot}158 + 0{\cdot}18 = 0$	4	$+0{\cdot}37$
74	$w + {\cdot}462 - {\cdot}837 - {\cdot}491 + 5{\cdot}108 + 0{\cdot}09 = 0$	2	$+0{\cdot}37$
75	$w - {\cdot}084 - {\cdot}946 - {\cdot}510 + 5{\cdot}017 + 0{\cdot}05 = 0$	3	$+0{\cdot}35$
76	$w - {\cdot}348 - {\cdot}887 - {\cdot}465 + 4{\cdot}974 + 0{\cdot}05 = 0$	2	$+0{\cdot}35$

No.	Equations.	Weights.	Residuals.
77	$w-0\cdot869x-0\cdot418y-0\cdot267z+4\cdot858\delta p+0''\cdot12=0$	3	$+0''\cdot30$
78	$w-\cdot965+\cdot042-\cdot204+4\cdot780+0\cdot16=0$	2	$+\cdot39$
79	$w-\cdot484+\cdot845-\cdot348+4\cdot619-0\cdot83=0$	5	$-0\cdot74$
80	$w-\cdot081+\cdot978-\cdot387+4\cdot547-0\cdot16=0$	7	$-0\cdot09$
81	$w+\cdot087+\cdot978-\cdot368+4\cdot518+0\cdot42=0$	4	$+0\cdot48$
82	$w+\cdot344+\cdot918-\cdot336+4\cdot473+0\cdot92=0$	5	$+0\cdot99$
83	$w+\cdot591+\cdot775-\cdot260+4\cdot424+0\cdot11=0$	4	$+0\cdot20$
84	$w+\cdot752+\cdot613-\cdot192+4\cdot386+0\cdot38=0$	4	$+0\cdot49$
85	$w+\cdot865+\cdot433-\cdot136+4\cdot351-0\cdot18=0$	10	$-0\cdot04$
86	$w+\cdot936+\cdot239-\cdot096+4\cdot316+0\cdot20=0$	3	$+0\cdot37$
87	$w+\cdot942-\cdot215-\cdot068+4\cdot241-0\cdot99=0$	2	$-0\cdot75$
88	$w+\cdot782-\cdot562-\cdot110+4\cdot177+0\cdot09=0$	6	$+0\cdot37$
89	$w+\cdot218-\cdot927-\cdot225+4\cdot066+0\cdot43=0$	3	$+0\cdot75$
90	$w-\cdot351-\cdot885-\cdot175+3\cdot973+0\cdot81=0$	1	$+1\cdot15$
91	$w-\cdot966-\cdot004+\cdot089+3\cdot789-0\cdot59=0$	1	$-0\cdot32$
92	$w-\cdot822+\cdot510+\cdot060+3\cdot699+1\cdot80=0$	2	$+1\cdot99$
93	$w-\cdot467+\cdot856-\cdot043+3\cdot616-0\cdot36=0$	1	$-0\cdot23$
94	$w-\cdot259+\cdot944-\cdot067+3\cdot578+0\cdot32=0$	1	$+0\cdot42$
95	$w+\cdot131+\cdot973-\cdot051+3\cdot510+0\cdot12=0$	2	$+0\cdot22$
96	$w+\cdot356+\cdot912-\cdot017+3\cdot471-0\cdot24=0$	1	$-0\cdot13$
97	$w+\cdot518+\cdot829+\cdot036+3\cdot440-0\cdot63=0$	5	$-0\cdot51$
98	$w+\cdot690+\cdot685+\cdot101+3\cdot401+0\cdot30=0$	5	$+0\cdot44$
99	$w+\cdot873+\cdot418+\cdot173+3\cdot348-0\cdot82=0$	5	$-0\cdot64$
100	$w+\cdot961+\cdot093+\cdot250+3\cdot292-1\cdot45=0$	4	$-1\cdot22$
101	$w+\cdot927-\cdot270+\cdot240+3\cdot231-0\cdot08=0$	5	$+0\cdot20$
102	$w-\cdot300-\cdot902+\cdot124+2\cdot982-0\cdot83=0$	1	$-0\cdot45$
103	$w-\cdot676-\cdot680+\cdot243+2\cdot911-0\cdot14=0$	2	$+0\cdot23$
104	$w-\cdot815-\cdot512+\cdot308+2\cdot875-0\cdot92=0$	3	$-0\cdot56$
105	$w-\cdot926-\cdot271+\cdot365+2\cdot832-0\cdot34=0$	1	$0\cdot00$
106	$w-\cdot961-\cdot091+\cdot400+2\cdot801+0\cdot41=0$	1	$+0\cdot73$
107	$w-\cdot566+\cdot792+\cdot282+2\cdot636-0\cdot13=0$	1	$+0\cdot05$
108	$w-\cdot391+\cdot900+\cdot249+2\cdot601+0\cdot06=0$	2	$+0\cdot22$
109	$w-\cdot271+\cdot941+\cdot251+2\cdot579-0\cdot56=0$	4	$-0\cdot41$
110	$w+\cdot060+\cdot980+\cdot230+2\cdot522-0\cdot05=0$	7	$+0\cdot08$
111	$w+\cdot345+\cdot917+\cdot289+2\cdot473-0\cdot03=0$	11	$+0\cdot11$
112	$w+\cdot580+\cdot784+\cdot357+2\cdot428+0\cdot60=0$	6	$+0\cdot76$
113	$w+\cdot748+\cdot619+\cdot442+2\cdot387+0\cdot95=0$	5	$+1\cdot14$
114	$w+\cdot824+\cdot509+\cdot460+2\cdot364-0\cdot05=0$	4	$+0\cdot16$
115	$w+\cdot966-\cdot029+\cdot548+2\cdot272-0\cdot56=0$	7	$-0\cdot27$

No.	Equations.	Weights.	Residuals.
116	$w+0{\cdot}879x-0{\cdot}398y+0{\cdot}535z+2{\cdot}208\delta p-0''{\cdot}17=0$	3	$+0''{\cdot}16$
117	$w+{\cdot}354-{\cdot}885+{\cdot}400+2{\cdot}088-0{\cdot}34=0$	4	$-0{\cdot}05$
118	$w-{\cdot}631-{\cdot}720+{\cdot}497+1{\cdot}921-0{\cdot}06=0$	3	$+0{\cdot}34$
119	$w-{\cdot}764-{\cdot}581+{\cdot}550+1{\cdot}890-(3{\cdot}40)=0$	0	$(-3{\cdot}00)$
120	$w-{\cdot}966+{\cdot}016+{\cdot}677+1{\cdot}785-0{\cdot}95=0$	3	$-0{\cdot}61$
121	$w-{\cdot}492+{\cdot}840+{\cdot}540+1{\cdot}621-0{\cdot}83=0$	4	$-0{\cdot}64$
122	$w-{\cdot}240+{\cdot}948+{\cdot}516+1{\cdot}574-0{\cdot}26=0$	4	$-0{\cdot}08$
123	$w-{\cdot}092+{\cdot}976+{\cdot}493+1{\cdot}549-0{\cdot}03=0$	3	$+0{\cdot}14$
124	$w+{\cdot}213+{\cdot}859+{\cdot}531+1{\cdot}496-0{\cdot}85=0$	4	$-0{\cdot}68$
125	$w+{\cdot}456+{\cdot}865+{\cdot}577+1{\cdot}452-0{\cdot}08=0$	5	$+0{\cdot}11$
126	$w+{\cdot}638+{\cdot}717+{\cdot}636+1{\cdot}407-0{\cdot}34=0$	4	$-0{\cdot}10$
127	$w+{\cdot}767+{\cdot}594+{\cdot}693+1{\cdot}382+0{\cdot}03=0$	6	$+0{\cdot}26$
128	$w+{\cdot}930+{\cdot}261+{\cdot}766+1{\cdot}320+0{\cdot}66=0$	3	$+0{\cdot}93$
129	$w+{\cdot}963-{\cdot}071+{\cdot}802+1{\cdot}265-0{\cdot}10=0$	6	$+0{\cdot}21$
130	$w+{\cdot}941-{\cdot}219+{\cdot}798+1{\cdot}240-0{\cdot}21=0$	2	$+0{\cdot}13$
131	$w+{\cdot}793-{\cdot}547+{\cdot}735+1{\cdot}170-0{\cdot}26=0$	3	$+0{\cdot}12$
132	$w+{\cdot}296-{\cdot}906+{\cdot}632+1{\cdot}079-0{\cdot}09=0$	5	$+0{\cdot}33$
133	$w-{\cdot}402-{\cdot}864+{\cdot}665+0{\cdot}964+1{\cdot}66=0$	$\frac{1}{2}$	$+2{\cdot}10$
134	$w-{\cdot}861-{\cdot}433+{\cdot}838+0{\cdot}861-0{\cdot}76=0$	1	$-0{\cdot}33$
135	$w-{\cdot}965+{\cdot}018+{\cdot}904+0{\cdot}784-0{\cdot}45=0$	1	$-0{\cdot}08$
136	$w-{\cdot}573+{\cdot}786+{\cdot}777+0{\cdot}637+0{\cdot}07=0$	1	$+0{\cdot}31$
137	$w-{\cdot}366+{\cdot}906+{\cdot}732+0{\cdot}597-1{\cdot}28=0$	3	$-1{\cdot}06$
138	$w-{\cdot}149+{\cdot}970+{\cdot}710+0{\cdot}559-0{\cdot}82=0$	4	$-0{\cdot}62$
139	$w+{\cdot}047+{\cdot}981+{\cdot}707+0{\cdot}525-0{\cdot}28=0$	5	$-0{\cdot}04$
140	$w+{\cdot}319+{\cdot}926+{\cdot}734+0{\cdot}477-0{\cdot}29=0$	6	$-0{\cdot}09$
141	$w+{\cdot}523+{\cdot}823+{\cdot}778+0{\cdot}439-0{\cdot}14=0$	5	$+0{\cdot}08$
142	$w+{\cdot}676+{\cdot}698+{\cdot}838+0{\cdot}405+0{\cdot}19=0$	4	$+0{\cdot}42$
143	$w+{\cdot}865+{\cdot}434+{\cdot}907+0{\cdot}351-1{\cdot}29=0$	3	$-1{\cdot}02$
144	$w+{\cdot}932+{\cdot}255+{\cdot}941+0{\cdot}320-0{\cdot}08=0$	6	$+0{\cdot}22$
145	$w+{\cdot}966-{\cdot}015+{\cdot}968+0{\cdot}275-0{\cdot}66=0$	9	$-0{\cdot}31$
146	$w+{\cdot}936-{\cdot}239+{\cdot}960+0{\cdot}236-0{\cdot}29=0$	7	$+0{\cdot}07$
147	$w-{\cdot}460-{\cdot}835+{\cdot}824-0{\cdot}045-0{\cdot}59=0$	2	$-0{\cdot}13$
148	$w-{\cdot}870-{\cdot}415+0{\cdot}974-0{\cdot}142-1{\cdot}11=0$	2	$-0{\cdot}68$
149	$w-{\cdot}944-{\cdot}203+1{\cdot}010-0{\cdot}178-0{\cdot}48=0$	4	$-0{\cdot}08$
150	$w-{\cdot}681+{\cdot}690+0{\cdot}923-0{\cdot}339-1{\cdot}61=0$	2	$-1{\cdot}34$
151	$w-{\cdot}450+{\cdot}868+{\cdot}834-0{\cdot}386-1{\cdot}30=0$	8	$-0{\cdot}76$
152	$w-{\cdot}180+{\cdot}963+{\cdot}802-0{\cdot}436-1{\cdot}09=0$	1	$-0{\cdot}88$
153	$w+{\cdot}075+{\cdot}979+{\cdot}807-0{\cdot}480-0{\cdot}74=0$	5	$-0{\cdot}54$
154	$w+{\cdot}325+{\cdot}924+{\cdot}838-0{\cdot}523-0{\cdot}28=0$	5	$-0{\cdot}07$

No.	Equations.	Weights.	Residuals.
155	$w+0{\cdot}457x+0{\cdot}864y+0{\cdot}851z-0{\cdot}548\delta p-1''{\cdot}33=0$	2	$-1''{\cdot}11$
156	$w+{\cdot}679+{\cdot}695+{\cdot}930-0{\cdot}594-0{\cdot}50=0$	3	$-0{\cdot}26$
157	$w+{\cdot}820+{\cdot}509+0{\cdot}980-0{\cdot}633-0{\cdot}35=0$	5	$-0{\cdot}08$
158	$w+{\cdot}948+{\cdot}182+1{\cdot}029-0{\cdot}693+0{\cdot}20=0$	1	$+0{\cdot}51$
159	$w+{\cdot}962-{\cdot}096+1{\cdot}047-0{\cdot}740+1{\cdot}84=0$	$\frac{1}{2}$	$+2{\cdot}20$
160	$w+{\cdot}905-{\cdot}336+1{\cdot}027-0{\cdot}780+0{\cdot}17=0$	3	$+0{\cdot}55$
161	$w+{\cdot}773-{\cdot}575+0{\cdot}974-0{\cdot}825-0{\cdot}96=0$	2	$-0{\cdot}55$
162	$w+{\cdot}337-{\cdot}892+{\cdot}834-0{\cdot}914-1{\cdot}26=0$	1	$-0{\cdot}91$
163	$w-{\cdot}734-{\cdot}619+0{\cdot}938-1{\cdot}102-0{\cdot}26=0$	1	$+0{\cdot}19$
164	$w-{\cdot}964-{\cdot}059+1{\cdot}048-1{\cdot}204-0{\cdot}30=0$	1	$+0{\cdot}09$
165	$w-{\cdot}332+{\cdot}920+0{\cdot}824-1{\cdot}410+0{\cdot}20=0$	2	$+0{\cdot}42$
166	$w-{\cdot}105+{\cdot}975+{\cdot}802-1{\cdot}449-0{\cdot}00=0$	5	$+0{\cdot}31$
167	$w+{\cdot}099+{\cdot}977+{\cdot}791-1{\cdot}484-0{\cdot}86=0$	5	$-0{\cdot}66$
168	$w+{\cdot}329+{\cdot}923+{\cdot}821-1{\cdot}524-0{\cdot}26=0$	6	$-0{\cdot}05$
169	$w+{\cdot}593+{\cdot}774+{\cdot}883-1{\cdot}577-0{\cdot}66=0$	3	$-0{\cdot}43$
170	$w+{\cdot}761+{\cdot}601+{\cdot}935-1{\cdot}617-0{\cdot}54=0$	7	$-0{\cdot}29$
171	$w+{\cdot}899+{\cdot}352+0{\cdot}979+1{\cdot}663-0{\cdot}34=0$	5	$-0{\cdot}05$
172	$w+{\cdot}965-{\cdot}030+1{\cdot}018-1{\cdot}729-1{\cdot}07=0$	6	$-0{\cdot}73$
173	$w+{\cdot}874-{\cdot}408+0{\cdot}976-1{\cdot}794-1{\cdot}89=0$	$\frac{1}{2}$	$-1{\cdot}50$
174	$w+{\cdot}682-{\cdot}677+{\cdot}882-1{\cdot}848-1{\cdot}91=0$	1	$-1{\cdot}49$
175	$w-{\cdot}720-{\cdot}635+{\cdot}875-2{\cdot}099+0{\cdot}63=0$	1	$+1{\cdot}07$
176	$w-{\cdot}909-{\cdot}323+{\cdot}936-2{\cdot}159-1{\cdot}61=0$	1	$-1{\cdot}20$
177	$w-{\cdot}959-{\cdot}115+{\cdot}958-2{\cdot}194-0{\cdot}43=0$	4	$-0{\cdot}05$
178	$w-{\cdot}490+{\cdot}842+{\cdot}755-2{\cdot}380-0{\cdot}35=0$	4	$-0{\cdot}12$
179	$w-{\cdot}376+{\cdot}903+{\cdot}746-2{\cdot}402+0{\cdot}90=0$	5	$+1{\cdot}11$
180	$w-{\cdot}209+{\cdot}955+{\cdot}713-2{\cdot}431+0{\cdot}72=0$	6	$+0{\cdot}92$
181	$w-{\cdot}029+{\cdot}980+{\cdot}690-2{\cdot}462+1{\cdot}40=0$	5	$+1{\cdot}59$
182	$w+{\cdot}102+{\cdot}975+{\cdot}677-2{\cdot}483+0{\cdot}51=0$	7	$+0{\cdot}70$
183	$w+{\cdot}311+{\cdot}930+{\cdot}694-2{\cdot}521-0{\cdot}34=0$	4	$-0{\cdot}15$
184	$w+{\cdot}406+{\cdot}888+{\cdot}710-2{\cdot}539+0{\cdot}35=0$	5	$+0{\cdot}54$
185	$w+{\cdot}525+{\cdot}824+{\cdot}730-2{\cdot}562-0{\cdot}08=0$	5	$+0{\cdot}12$
186	$w+{\cdot}675+{\cdot}700+{\cdot}773-2{\cdot}595+0{\cdot}01=0$	6	$+0{\cdot}23$
187	$w+{\cdot}934+{\cdot}250+{\cdot}866-2{\cdot}682-0{\cdot}31=0$	8	$-0{\cdot}02$
188	$w+{\cdot}966-{\cdot}024+{\cdot}888-2{\cdot}727+0{\cdot}19=0$	3	$+0{\cdot}51$
189	$w+{\cdot}917-{\cdot}303+{\cdot}853-2{\cdot}775+0{\cdot}06=0$	4	$+0{\cdot}42$
190	$w+{\cdot}763-{\cdot}588+{\cdot}855-2{\cdot}828+0{\cdot}02=0$	1	$+0{\cdot}42$
191	$w-{\cdot}558-{\cdot}775+{\cdot}659-3{\cdot}064+0{\cdot}74=0$	2	$+1{\cdot}17$
192	$w-{\cdot}801-{\cdot}527+{\cdot}716-3{\cdot}119+0{\cdot}09=0$	2	$+0{\cdot}50$
193	$w-{\cdot}961-{\cdot}100+{\cdot}772-3{\cdot}197+0{\cdot}61=0$	1	$+0{\cdot}97$

No.	Equations.	Weights.	Residuals.
194	$w-0\cdot938x+0\cdot231y+0\cdot768z-3\cdot251\delta p+1\cdot19=0$	1	+1″·49
195	$w-\cdot660+\cdot712+\cdot619-3\cdot343+0\cdot49=0$	2	+0·72
196	$w-\cdot367+\cdot905+\cdot544-3\cdot403-0\cdot75=0$	3	−0·56
197	$w-\cdot117+\cdot974+\cdot501-3\cdot445+0\cdot31=0$	7	+0·48
198	$w+\cdot117+\cdot975+\cdot382-3\cdot487-1\cdot36=0$	3	−1·21
199	$w+\cdot444+\cdot871+\cdot516-3\cdot547+0\cdot31=0$	7	+0·48
200	$w+\cdot653+\cdot721+\cdot568-3\cdot589+0\cdot04=0$	4	+0·24
201	$w+\cdot805+\cdot540+\cdot615-3\cdot629-0\cdot29=0$	7	−0·07
202	$w+\cdot892+\cdot370+\cdot641-3\cdot661-1\cdot08=0$	4	−0·83
203	$w+\cdot920-\cdot294+\cdot631-3\cdot773-0\cdot39=0$	2	−0·06
204	$w+\cdot540-\cdot791+\cdot460-3\cdot878+0\cdot54=0$	2	+0·92
205	$w+\cdot319-\cdot899+\cdot395-3\cdot918-(2\cdot70)=0$	0	(−2·30)
206	$w-\cdot512-\cdot805+\cdot458-4\cdot056-0\cdot25=0$	2	+·016
207	$w-\cdot894-\cdot360+\cdot514-4\cdot153-0\cdot16=0$	1	+0·20
208	$w-\cdot961-\cdot086+\cdot529-4\cdot199-0\cdot74=0$	1	−0·41
209	$w-\cdot460+\cdot861+\cdot290-4\cdot386-0\cdot04=0$	8	+0·13
210	$w-\cdot204+\cdot958+\cdot226-4\cdot433-1\cdot01=0$	4	−0·87
211	$w-\cdot007+\cdot982+\cdot206-4\cdot466+0\cdot09=0$	8	+0·22
212	$w+\cdot218+\cdot956+\cdot209-4\cdot501-0\cdot35=0$	4	−0·22
213	$w+\cdot466+\cdot858+\cdot237-4\cdot550-0\cdot31=0$	13	−0·16
214	$w+\cdot759+\cdot607+\cdot291-4\cdot616-0\cdot40=0$	9	−0·23
215	$w+\cdot909+\cdot328+\cdot366-4\cdot668-0\cdot24=0$	5	−0·02
216	$w+\cdot962-\cdot082+\cdot364-4\cdot737-0\cdot40=0$	10	−0·13
217	$w+\cdot913-\cdot313+\cdot332-4\cdot777-0\cdot38=0$	2	−0·08
218	$w+\cdot731-\cdot626+\cdot211-4\cdot837-0\cdot65=0$	2	−0·32
219	$w+\cdot604-\cdot746+\cdot229-4\cdot865-0\cdot69=0$	1	−0·34
220	$w-\cdot832-\cdot484+\cdot194-5\cdot130-1\cdot45=0$	½	−1·11
221	$w-\cdot413+\cdot883-\cdot013-5\cdot393-0\cdot87=0$	2	−0·74
222	$w-\cdot216+\cdot955-\cdot061-5\cdot428-0\cdot01=0$	1	+0·10
223	$w+\cdot260+\cdot946-\cdot098-5\cdot513-0\cdot34=0$	4	−0·24
224	$w+\cdot430+\cdot878-\cdot067-5\cdot544-0\cdot85=0$	3	−0·74
225	$w+\cdot617+\cdot754-\cdot033-5\cdot581-0\cdot41=0$	4	−0·29
226	$w+\cdot739+\cdot630+\cdot009-5\cdot611-0\cdot07=0$	8	+0·07
227	$w-\cdot476-\cdot827-\cdot217-6\cdot049-0\cdot61=0$	2	−0·28
228	$w-\cdot794-\cdot543-\cdot142-6\cdot119-1\cdot05=0$	1	−0·74
229	$w+\cdot786+\cdot567-\cdot280-6\cdot624-0\cdot86=0$	1	−0·71
230	$w+\cdot233-\cdot923-\cdot521-6\cdot932-0\cdot87=0$	1	−0·58
231	$w-\cdot128-\cdot942-\cdot537-6\cdot991+0\cdot41=0$	3	+0·70
232	$w-\cdot613-\cdot755-\cdot471-7\cdot075-0\cdot99=0$	2	−0·70

No.	Equations.	Weights.	Residual.
233	$w-0{\cdot}505x+0{\cdot}833y-0{\cdot}578z-7{\cdot}377\delta p-0''{\cdot}56=0$	3	$-0''{\cdot}49$
234	$w+\ {\cdot}022+{\cdot}980-{\cdot}670-7{\cdot}471-0{\cdot}32=0$	3	$-0{\cdot}30$
235	$w+\ {\cdot}190+{\cdot}963-{\cdot}695-7{\cdot}500-1{\cdot}85=0$	1	$-1{\cdot}83$
236	$w+\ {\cdot}511+{\cdot}832-{\cdot}621-7{\cdot}559-0{\cdot}61=0$	8	$-0{\cdot}57$
237	$w+\ {\cdot}675+{\cdot}699-{\cdot}577-7{\cdot}595-1{\cdot}41=0$	8	$-1{\cdot}35$
238	$w+\ {\cdot}814+{\cdot}526-{\cdot}534-7{\cdot}631-0{\cdot}17=0$	8	$-0{\cdot}08$
239	$w+\ {\cdot}934+{\cdot}247-{\cdot}508-7{\cdot}682+0{\cdot}62=0$	3	$+0{\cdot}74$
240	$w+\ {\cdot}964-{\cdot}048-{\cdot}498-7{\cdot}731-0{\cdot}28=0$	5	$-0{\cdot}12$
241	$w+\ {\cdot}871-{\cdot}416-{\cdot}558-7{\cdot}796+0{\cdot}14=0$	1	$+0{\cdot}34$
242	$w+\ {\cdot}559-{\cdot}777-{\cdot}691-7{\cdot}874-0{\cdot}22=0$	1	$+0{\cdot}02$
243	$w+\ {\cdot}415-{\cdot}861-{\cdot}754-7{\cdot}902-2{\cdot}27=0$	1	$-2{\cdot}04$
244	$w-\ {\cdot}441+{\cdot}870-{\cdot}818-8{\cdot}390+0{\cdot}65=0$	5	$+0{\cdot}67$
245	$w-\ {\cdot}188+{\cdot}962-{\cdot}871-8{\cdot}435+1{\cdot}04=0$	9	$+1{\cdot}05$
246	$w+\ {\cdot}060+{\cdot}980-{\cdot}889-8{\cdot}478+1{\cdot}46=0$	2	$+1{\cdot}46$
247	$w+\ {\cdot}231+{\cdot}954-{\cdot}882-8{\cdot}507+0{\cdot}54=0$	6	$+0{\cdot}54$
248	$w+\ {\cdot}431+{\cdot}878-{\cdot}852-8{\cdot}546+0{\cdot}65=0$	8	$+0{\cdot}66$
249	$w+\ {\cdot}592+{\cdot}775-{\cdot}820-8{\cdot}576+0{\cdot}14=0$	3	$+0{\cdot}16$
250	$w+\ {\cdot}721+{\cdot}650-{\cdot}763-8{\cdot}607+0{\cdot}71=0$	4	$+0{\cdot}75$
251	$w+\ {\cdot}818+{\cdot}520-{\cdot}734-8{\cdot}634+0{\cdot}04=0$	4	$+0{\cdot}10$
252	$w+\ {\cdot}905+{\cdot}338-{\cdot}704-8{\cdot}667+0{\cdot}00=0$	4	$+0{\cdot}09$
253	$w+\ {\cdot}957+{\cdot}134-{\cdot}689-8{\cdot}701+0{\cdot}70=0$	3	$+0{\cdot}81$
254	$w+\ {\cdot}964-{\cdot}063-{\cdot}692-8{\cdot}735-0{\cdot}43=0$	2	$-0{\cdot}28$
255	$w+\ {\cdot}916-{\cdot}306-{\cdot}719-8{\cdot}776-1{\cdot}13=0$	2	$-0{\cdot}96$
256	$w+\ {\cdot}815-{\cdot}514-{\cdot}766-8{\cdot}813+0{\cdot}49=0$	$1\frac{1}{2}$	$+0{\cdot}68$
257	$w+\ {\cdot}491-{\cdot}821-{\cdot}886-8{\cdot}887-0{\cdot}55=0$	1	$-0{\cdot}32$
258	$w-\ {\cdot}441+{\cdot}869-{\cdot}936-9{\cdot}389-0{\cdot}25=0$	3	$-0{\cdot}23$
259	$w-\ {\cdot}301+{\cdot}930-{\cdot}978-9{\cdot}415+0{\cdot}30=0$	2	$+0{\cdot}30$
260	$w-\ {\cdot}082+{\cdot}978-0{\cdot}999-9{\cdot}453+0{\cdot}80=0$	5	$+0{\cdot}79$
261	$w+\ {\cdot}056+{\cdot}979-1{\cdot}010-9{\cdot}480-0{\cdot}98=0$	3	$-0{\cdot}99$
262	$w+\ {\cdot}273+{\cdot}942-0{\cdot}996-9{\cdot}514-1{\cdot}65=0$	5	$-1{\cdot}66$
263	$w+\ {\cdot}599+{\cdot}769-{\cdot}913-9{\cdot}577-1{\cdot}45=0$	5	$-1{\cdot}44$
264	$w+\ {\cdot}828+{\cdot}503-{\cdot}847-9{\cdot}636-1{\cdot}89=0$	5	$-1{\cdot}84$
265	$w+\ {\cdot}922+{\cdot}287-{\cdot}804-9{\cdot}675-0{\cdot}91=0$	6	$-0{\cdot}83$
266	$w+\ {\cdot}964+{\cdot}065-{\cdot}786-9{\cdot}712-1{\cdot}33=0$	5	$-1{\cdot}22$

Out of the entire number, three observations have been rejected, viz. those made on 1864, February 9, 1866, February 13, and 1869, December 1. These give very discordant results, and in the first two instances the readings of one of the micrometers have been altered, which throws a certain amount of suspicion on the observations. In the third case the bisection

of the star's image with the micrometer wire was made when the star was very near the edge of the field. The rejection of these observations reduces the effective number of the equations of condition to 264.

As a general rule, the weight assigned to an equation of condition is the same as the number of observations contained in the group of observed Z. D.'s corresponding to the equation; but in some cases half weight has been given to an observation when it was made under very unfavourable circumstances.

Applying the method of least squares to the 264 equations of condition, I find the normal equations to be

$$\begin{aligned}
&+\ 1038w + 264{\cdot}445x + 419{\cdot}123y - 93{\cdot}978z + 902{\cdot}606\delta p - 172{\cdot}81 = 0\\
&+264{\cdot}445 + 446{\cdot}723 + 98{\cdot}288 + 31{\cdot}426 - 448{\cdot}785 - 43{\cdot}39 = 0\\
&+419{\cdot}123 + 98{\cdot}288 + 526{\cdot}628 - 28{\cdot}858 - 275{\cdot}246 - 24{\cdot}18 = 0\\
&-\ 93{\cdot}978 + 31{\cdot}426 - 28{\cdot}858 + 512{\cdot}619 - 1310{\cdot}491 - 42{\cdot}84 = 0
\end{aligned}$$

Solving these, I find the following values of the unknown quantities :—

$w = +0''{\cdot}236 - 0{\cdot}887\delta p$,	Weight (putting $\delta p = 0$)	608·580
$x = -0{\cdot}022 + 1{\cdot}448$	„ „	373·019
$y = -0{\cdot}131 - 0{\cdot}358$	„ „	356·990
$z = +0{\cdot}121 + 2{\cdot}285$	„ „	495·730

From these values we have

Mean Z. D. North of γ *Draconis* for 1866·0	$= 102''{\cdot}606$	$-0{\cdot}887\ \delta p$
Constant of Aberration	$= 20{\cdot}378$	$+1{\cdot}448$
Annual Parallax of γ *Draconis* ...	$= -0{\cdot}131$	$-0{\cdot}358$
Constant of Nutation for 1866 ...	$= 9{\cdot}3353$	$+2{\cdot}1076$

The residuals given above have been formed by assuming $\delta p = 0$, and from them I find sum of

$$\text{Weight} \times \text{Square of residual} = 343{\cdot}917$$

(the sum of weight × square of absolute term is 391·145), and therefore the probable error of an observation of weight unity is $\pm 0''{\cdot}776$, and combining this with the weights of w, x, y and z given above we have

Probable error of w	$= \pm 0''{\cdot}031$
„	$x = \pm 0{\cdot}040$
„	$y = \pm 0{\cdot}041$
„	$z = \pm 0{\cdot}035$

Therefore, finally, assuming $\delta p = 0$, we have

Mean Z. D. North of γ *Draconis*, 1866·0	=	102″·606	± 0″·031
Constant of Aberration	=	20·378	± 0·040
Annual Parallax of γ *Draconis* ...	= −	0·131	± 0·041
Constant of Nutation for 1866 ...	=	9·3353	± 0·0323

It will be remarked that the parallax of γ *Draconis* again comes out a negative quantity, and as it is three times greater than its probable error we cannot regard it as accidental. It is, however, somewhat smaller than the quantity found by Main, whilst at the same time the constant of aberration is larger, so that the results of the present discussion are rather more satisfactory. It must, however, be assumed that there is a periodic error of some kind which affects the determination of annual parallax (perhaps arising from the effect of temperature on the instrument), and which therefore tends to throw a certain amount of suspicion on the value of the constant of aberration here deduced.

The above value of the constant of nutation agrees closely with that found by Main from the observations of γ *Draconis*, made with the 25-foot Zenith Tube.

As mentioned above, the probable error of an observation is $\pm 0''.776$. The corresponding quantity for the Transit Circle is, in the case of a star near the zenith, $\pm 0''.47$. The larger quantity found for the Reflex Zenith Tube may partly be accounted for by the difficulty of obtaining a perfectly satisfactory image by reflexion from mercury; and partly by the remarkable circumstance that, in this latitude, the sky is seldom quite dark when a star of 18^h Right Ascension is passing the meridian. It may also be remarked that considerable difficulty is experienced in observing γ *Draconis* with the Reflex Zenith Tube during the daytime, and that really comparatively few observations are made when the aberration has its greatest effect—*i.e.* when the star passes the meridian at six o'clock (mean time) in the morning or evening, so that the series of observations here discussed is not so favourable for a determination of the constant of aberration as might *à priori* be imagined.

Royal Observatory, Greenwich:
1882, *May* 11.

Remarks on an Apparatus for determining those Errors of astronomical Observations which are caused by the Flexures of an Instrument and by Defects in the Shape of its Pivots. By A. Marth, Esq.

At the meeting of last December, in the course of the discussion on Mr. Stone's paper on a new form of Transit-Circle, I stated that in the spring of 1862 I had published * a proposal of a new method for determining the flexure- and pivot-errors, which was specially applicable in the case of an instrument with a prism in the centre—a case to which Mr. Stone had alluded. I mentioned that in 1869 an apparatus such as I proposed had been constructed by Messrs. T. Cooke & Sons, of York, for a Transit-Circle with telescope of the ordinary form, and that the instrument was still at their works. I further remarked that, in December 1878, there had appeared in the "Comptes Rendus" of the Paris Academy a paper by M. Loewy, in which he raised some objections to my proposal which had been a great puzzle to me; that, while in his own proposal M. Loewy had adopted the principle of my method, he had made alterations in its application about which astronomers would form their own judgment by-and-by. I mentioned also that Messrs. Cooke would probably bring or send up their apparatus for inspection at one of our meetings, so that those who take an interest in the matter—and especially Mr. Stone—might criticise it and compare it with M. Loewy's, of which a description had lately appeared.

The apparatus is to be shown at the May meeting, and I will, therefore, now offer some explanatory remarks. But before doing so, it will be desirable or even essential, on account of some extraordinary assertions which M. Loewy makes in the April number of the *Monthly Notices*, that I should first submit to the critical consideration of readers a preliminary question referring to elementary geometrical optics.

If a distant object is looked at through a refracting telescope, how is the place of the object's image in the field of view affected by some slight shifting of the object-glass?

The question must have presented itself to every thinking observer who uses an astronomical instrument intelligently, so that there should be no difficulty in getting an answer, even if the text-books are silent about it. I have not been aware that there was or could be a doubt about the correctness of the answer, that the effect of the shifting depends entirely upon the shifting of the *optical centre* of the object-glass (if by optical centre is understood that point where the straight lines cross which join the points of an infinitely distant object with the

* *Astr. Nachrichten*, No. 1361 in Vol. LIII. "Vorschlag eines neuen Verfahrens, die von der Biegung eines Instruments und von den Unregelmässigkeiten seiner Zapfen erzeugten astronomischen Beobachtungsfehler zu bestimmen."

corresponding points of its image), and that any slight shifting of the object-glass round its optical centre does *not* affect the line of vision or the direction in which the object appears. I cannot find, at present, any flaw in the reasoning which leads to this conclusion. But if the answer is really wrong, I shall be much obliged to any reader who will enlighten me (and probably others) about what is the truth in the matter, and I shall *then* most readily acknowledge that I have been all along under a delusion respecting an elementary question of practical optics.

The exact position of the optical centre and other cardinal points in any system of lenses on a common axis may be determined either from the optical elements of the system, in case these are known, or by means of special experiments, the theory having been cleared up by the dioptrical investigations of Gauss * and Bessel † published nearly simultaneously at the beginning of 1841.

As some readers may be interested to get distinct notions of the actual forms of two celebrated object-glasses, of which the optical elements are known, they will perhaps avail themselves of the following data for the graphical representation of sections of these glasses passing through the axis of the lenses. The x abscissæ, expressed in English inches, are reckoned along the axis from the centre of the outer surface of the crown lens, the y ordinates perpendicular to the axis.

Object-glass of the Koenigsberg Heliometer.

The elements of its construction are given on p. 101 of Bessel's "Astr. Untersuchungen."

		$y=0$	$\pm 1{\cdot}07$	$\pm 2{\cdot}13$	$\pm 3{\cdot}20$
Crown lens	$x=0{\cdot}0$		·008	·031	·069
	$=0{\cdot}234$	First principal point.			
	$=0{\cdot}533$		·514	·456	·360
Flint lens	$=0{\cdot}533$		·514	·458	·363
	$=0{\cdot}556$	Second principal point = optical centre.			
	$=0{\cdot}888$		·883	·866	·839

Focal length $100^{\text{in}}{\cdot}50$, effective aperture $6^{\text{in}}{\cdot}23$.

Object-glass of the great Washington Equatoreal.

According to Prof. Holden's "Investigation of the Objective and Micrometers of the Twenty-six Inch Equatoreal" (Appendix

* Gauss, "Dioptrische Untersuchungen," *Werke*, Bd. V. The optical centre in the sense of the term as used above, is identical with the point called by Gauss "zweiter Hauptpunkt."

† Bessel, "Ueber die Grundformeln der Dioptrik," *Astr. Nachr.* No. 415. Cf. in the *Briefwechsel zwischen Gauss und Bessel* the letters No. 179 and 180, exchanged in January 1841. The further investigations of Bessel must be studied in the "Besondere Untersuchung des Heliometers . . . . ," the second paper of his *Astron. Untersuchungen.*

I. of Wash. Obs. for 1877), the elements of its construction are approximately (using the notation employed by Bessel)—

	in.	
$r = +$	161·39	$n = 1{\cdot}5172$
$d =$	1·884	
$\rho = -$	161·39	
$e =$	0·029	
$r' = -$	162·07	$n' = 1{\cdot}6280$
$d' =$	0·958	
$\rho' = -$	19466·	

Hence the coordinates for graphical representation of a section of the object-glass:

	$y =$	0	±3	±6	±9	±12	±13	±13·6
	$x = -0{\cdot}344$	First principal point.						
Crown lens	=	0·0	0·028	0·112	0·251	0·447	0·524	0·574
	=	0·669	Second principal point = optical centre.					
	=	1·884	1·856	1·772	1·633	1·437	1·360	1·310
Flint lens	=	1·913	1·885	1·802	1·663	1·468	1·391	1·341
	=	2·871	2·871	2·870	2·869	2·867	2·867	2·866

The focal length, deduced from the assumed elements by means of the catenary fraction employed by Bessel, is 389·12 inches; Prof. Holden, using a modification of Gauss's formulæ, finds it = 389·66 inches.

While the optical centre of the object-glass of the Koenigsberg Heliometer is a little within the flint lens very near to the point where the two lenses touch, that of the great Washington object-glass is within the crown lens, at about one-third of its thickness from the outer surface.

With the exception of a few cases, the elements of the construction of the object-glasses employed are not known to observers. The exact places of the optical centres cannot, on that account, be computed, and their practical determination is only feasible where the means are available for making proper experiments for the purpose. For ordinary observations a knowledge of the position of the optical centre may, indeed, be dispensed with; it may be sufficient to know that there is such a point through which the line of vision passes. In applying my method for determining flexure, in which a marked point on the object-glass is observed, it will be desirable to know the place of the optical centre at least approximately, so that the effect of any shifting of the object-glass may be duly estimated.

I will now proceed to explain how my old proposal of an apparatus for determining the astronomical errors which affect the line of vision has been carried out in Messrs. Cooke's

apparatus which is to be shown at the meeting. The Transit-Circle to which the apparatus belongs has an object-glass of 7 inches aperture and 88 inches focal length. The pivots of the axis have apertures of $2\frac{1}{4}$ inches diameter in order to allow the determination of the errors arising from flexure of the axis and shape of the pivots. The axis of the instrument is cast in one piece; the middle part is 13 inches across and has in the middle of its two exposed sides apertures in the form of squares of 4 inches, with rounded-off corners. Usually these apertures are closed by covers, which are held in their places by press-clamps attached to the instrument. When the flexure-apparatus is to be used, these covers (which together have the same weight as the apparatus, about 14 lbs.) are removed and the apparatus is inserted so that its stout end-pieces or end-plates fill the apertures, and are held there so that the clamped parts are flush with the sides of the instrument. The stout end-plates fit very closely, but some small portions of the metal are to be taken off on two sides of the apparatus in order to allow the insertion of wedges so as to guard against any possibility of shake. The connection of the apparatus with the central part of the instrument is very strong and yet very simple; in planning this connection it was made a condition that the apparatus should be fit to be placed in the right position without troublesome preparations, so that it might be ready for use at any spare time in the regular course of observations. The middle part of the apparatus contains a plane-parallel glass between two achromatic object-glasses of $2\frac{1}{2}$ inches aperture and of nearly half the focal length of the chief object-glass. One half of the plane glass is to be silvered on both sides, so that the silvered half may serve as a mirror. The silvered portion may be the middle or the outer part; or a half-circle or the whole may be silvered, according to the observer's judgment. The frame which holds the mirror may be taken out and inserted in the reversed position; of course, proper care must be taken to fasten it so as to guard against any possibility of shake. The two small object-glasses must be so placed that the mark on the great object-glass is in the focal plane of the one, while the focus of the other is in the plane of the webs at the eye-end. In order to enable the observer to effect exact focussing, the cells of the small object-glasses can be slowly moved in the direction of their axes by being turned round with the help of wheel-work, the last wheels of which are outside the end-plates of the apparatus, within the handles, where they may be turned from the eye-end. After focussing, the cells may be further fastened, if need be; but, as an inspection of the apparatus will show, Messrs. Cooke's contrivance is so well executed that the precaution will probably be found superfluous.

When the apparatus and the illumination are got ready, there are to be seen in the field of view: the webs, their image reflected by the mirror, and the image of the cross-lines by

which the chief object-glass is marked. The relative positions of these images (in the direction of the transit-observations as well as of the circle-observations) are then to be measured in different directions of the telescope. The measured changes in the relative positions of the images are the effect of the flexure of the telescope, yet mixed up with some possible changes in the position of the mirror relative to the parts of the instrument where the apparatus is fastened, and also with some possible changes in the relative position of the optical centres of the two small object-glasses. Moreover, the line of vision is thus referred to the actual axis of rotation of the apparatus, the direction of which is liable to change on account of flexure of the axis of the instrument, and of possible irregularities in the pivots and their supports. For the determination of the united effect of these latter sources of error, the flexure apparatus carries at the side facing one of the pivots a plane mirror. Further, on an entirely independent support, outside of the instrument, an auxiliary telescope with micrometer, &c., is to be firmly mounted, so that it points through the aperture in the pivot of the Transit-Circle to the side-mirror of the flexure-apparatus. By bringing the (horizontal and vertical) webs of the auxiliary micrometer to coincidence with their image reflected from the side mirror, and making the observation for many readings of the Transit-Circle, the coordinates of the curve become known which the normal to the mirror describes on the sphere, and from them the effect of the flexure of the axis and of the pivot-errors upon the line of vision of the Transit-Circle telescope is found.

In order to examine and to eliminate the effects of any possible changes in the position of the central mirror, &c., and of other possible sources of error, the flexure-apparatus is to be reversed as well in regard to the axis of the telescope as in regard to the axis of rotation, and the observations are to be made in the four positions of the apparatus. I will not dilate, at present, further on this question. As my remarks are intended for critical readers who are capable of forming a judgment of their own, and who are sufficiently interested in the subject not to mind the trouble of looking over my old paper of 1862, I should be obliged for their critical examination of what I have stated there on this point, so that we may get at the truth. They will perhaps also form their own judgment on the curious objections and assertions which M. Loewy makes in his paper in the last number of the *Monthly Notices*, and on which I shall have something to say in the next number.

At the December meeting I stated that my old proposal was especially applicable in the case of an instrument with a prism in the centre, as, in fact, I had mentioned long ago in the introductory remarks of my old paper. The advantages of such an instrument are obvious: one of the most important, where the highest attainable accuracy is required, is the absence of a very serious source of error—namely, the presence of the observer's

body underneath or close to the instrument. The question whether it is preferable to break the line of vision by a prism or by a piece of silvered glass will be settled by considerations of the available facilities for renewing the silvered surface. If a prism is preferred, I may perhaps mention an old suggestion of mine to make use of an elongated prism, of which only the middle part need be brought to perfection for reflection, while the ends are to serve for the firmer mounting of the prism. But I will not enter here into considerations of the proper construction of the middle part of the axis of the instrument for securing strength and the firm mounting of the prism and of the flexure-apparatus. I will merely indicate the simplified conditions which the latter has to fulfil. The side-mirror, of course, disappears. As the apparatus is mounted near the prism at the side of the eye-end, the lenses and the mirror turn, with the telescope, round their own axes, and reversion with regard to the line of vision becomes superfluous. The small object-glasses, the apertures of which ought not to be less than the side of the prism, are now of unequal focal length, since, for the sake of using a prism of moderate size, the distance to the webs in the eye-end will probably be made considerably shorter than that to the mark on the great object-glass. The flexure-apparatus will perhaps be best so arranged that both the small object-glasses may be taken out and the (fully) silvered mirror put in place of that farthest from the eye-end. When the eye-end micrometer is removed and the auxiliary telescope employed, the curve described by the normal to the plane of the mirror is referred to a fixed direction. If, then, the small object-glass nearest the eye-end is inserted, and the eye-end micrometer reinserted and adjusted, the observed coincidences of the webs with their reflected image will refer the positions of the webs to the normal of the mirror. If, further, the mirror is replaced by the other object-glass, the changes of the image of the mark in reference to a zero point of the net of webs will show the effect of the flexure of the telescope-tube and of the bending of the prism, this effect multiplied by the proportion of the focal lengths of the two object-glasses and added to the changes of the zero point. These experiments may then be varied, &c. But the hints here given will perhaps be sufficient for thinking readers who take an interest in the problem, to induce them to consider it in all its bearings, and I must leave it to those astronomers who have means and opportunities to get ideas carried out in practice, whether they will avail themselves of these suggestions.

On the Spectrum of Comet a, 1882 (Wells), observed at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The spectrum of this object was first examined on the evening of April 22, with the Single-prism spectroscope. No bright bands could be detected, but a continuous spectrum was traced from about λ 5900 to λ 4900. This spectrum was very fairly bright from the star-like nucleus, and a faint spectrum could also be perceived some little distance down the tail.

The comet was observed again with the same instrument on April 24, when the continuous spectrum was traced from about λ 6000 to λ 4400. This spectrum was not equally bright throughout, there being two ill-defined maxima in the green and greenish-blue, but no bright bands could be made out.

On May 11 the "Half-prism" spectroscope was employed, with one half-prism, reversed as in the observations of prominences, so as to give great purity of spectrum. No bright bands could be seen, nor any irregularities of brightness or break of continuity detected in the continuous spectrum which was traced from about λ 6000 to about λ 4700. The continuous spectrum seemed remarkably bright from the nucleus, considering the comparative faintness of the comet, and the high dispersion used, viz. 5° from A to H, the magnifying power being 28. The observations were made by Mr. Maunder throughout.

Royal Observatory, Greenwich:
1882, *May* 12.

Elements of the Orbit of Comet Wells. By A. Graham, Esq.

(*Communicated by Professor Adams.*)

From the following observations of the Comet Wells, made at this Observatory with the Northumberland Equatoreal and square-bar Micrometer, under favourable conditions, after carefully correcting for aberration and parallax, I have obtained parabolic elements of the orbit, which may be of some value in tracing its course until better elements are forthcoming.

Observed places:—

G.M.T.	R.A.	N. Declination.
	h m s	° ′ ″
1882, April 5·42729	18 26 49·06	44 0 58·3
14·42002	18 51 32·80	51 32 15·1
22·42595	19 24 55·81	59 21 17·6
·45297	25 4·09	22 59·9

Elements of orbit :—

$$\left.\begin{array}{l} T = 1882, \text{ June } 10{\cdot}58295, \text{ G.M.T.} \\ \pi = 53^\circ\ 53'\ 48''{\cdot}2 \\ \Omega = 205\ \ 2\ \ 0{\cdot}8 \end{array}\right\} \text{Mean Equinox } 1882{\cdot}0.$$

$$i = 73\ 52\ 54{\cdot}6$$

$$\log q = 8{\cdot}788203. \quad \text{Motion direct.}$$

Comparison with middle place (C—O) :—

$$\Delta \mathrm{L} \cos l = 3''{\cdot}4 \qquad \Delta l = -0''{\cdot}3.$$

Heliocentric equatoreal coordinates, referred to apparent equinox and obliquity, April 1 :—

$$x = [9{\cdot}9607526]\ r \sin (126^\circ\ 15'\ 11''{\cdot}2 + v)$$
$$y = [9{\cdot}8607709]\ r \sin (\ 61\ 12\ 38{\cdot}4 + v)$$
$$z = [9{\cdot}9026397]\ r \sin (196\ 41\ 38{\cdot}6 + v).$$

where r = radius vector, and v = true anomaly of the comet.

Satisfactory comparisons with the star numbered 6093 in the Radcliffe Catalogue for 1845 were obtained on May 10. These give for the correction of the Ephemeris deduced from the above elements

$$\Delta \alpha \,.\, \cos \delta = +4^s{\cdot}36\,; \qquad \Delta \delta = -1''{\cdot}2.$$

Cambridge Observatory:
1882, May 11.

An Examination of the Roorkee Observations of the Transit of Venus, 1874, December 8. By Col. J. F. Tennant, R.E., F.R.S.

It was proposed by Sir George Airy that the observations of this transit should be reduced, so that the results of observations should be shown in the form of equations of condition, their further discussion being left to be taken up by some person in whom there should be general confidence after the whole had been so reduced. In accordance with these views I was instructed by the Government of India to reduce my observations in this manner, and the results of these were published in 1877 in a Report which has, I believe, been largely distributed through the Royal Observatory.

Since that time a Parliamentary Paper was issued in which the contact observations made by the observers whose expenses were defrayed from the Parliamentary Grants were compared and a value of the solar parallax deduced. Colonel Tupman then, in a Paper published in the *Monthly Notices*, vol. xxxviii., discussed these, with the addition of a number of observations by British observers, among which were those I had made at

Roorkee. As a result, he ascribed a considerable error to my observed Contact at Ingress, which he considered was late observed, and rejected it in his deduction of parallax, on which, indeed, it would have produced little effect. Disagreeing in his conclusion, I recently wrote to him, pointing out that the observation did not stand alone, and that the micrometer observations confirmed its accuracy. Colonel Tupman admits this, but I think that an examination of my results may be interesting to the Society, especially as I saw what I believed to be geometric contacts free from all halo, black drop, or other peculiarity. I am aware of no details of other micrometer observations than my own, and I much regret that they have not been reduced and published, as the discussion of them would, I feel sure, have led to confidence in them.

Comparison of Cusp Distances with Observed Contacts.

At page 40 of my Report the following values are given of the time of contact as deduced from the cusp measures, the third being corrected by half a minute:—

h	m	s		
12	42	44·6	−22·461 Δσ	+0·011 ΔS
		42·0	−14·215	+0·009
		40·0	− 9·738	+0·006
		39·3	− 3·643	+0·003

It will not much matter what value is assigned to ΔS, the correction to the solar semi-diameter. I will assume it as $-1''\cdot85$, as found at Greenwich, and then I find the most probable value of Δσ is $0''\cdot29$, and of the time of contact, T, it is $12^h\ 42^m\ 37^s\cdot7$. The several observations give $38^s\cdot2$, $37^s\cdot7$, $37^s\cdot1$, $38^s\cdot1$, as the values of the seconds for contact. I have weighted the observations equally in this deduction, and it is evident that it cannot matter how the weights are assigned to the equations in determining Δσ. If the above value of Δσ be substituted in the weighted mean value of the time at page 41, the result will be $38^s\cdot1$ for the time of contact.

It is evident that the values of the contact time from the cusp measures at Egress (p. 42) will not admit of this treatment. They are

$$T_2 = \begin{cases} 16^h\ 28^m\ 28^s\cdot7 + 9\cdot561\,\Delta\sigma - 0\cdot006\,\Delta S \\ \qquad\qquad 34\cdot9 + 12\cdot722 \quad -0\cdot008 \\ \qquad\qquad 26\cdot8 + 18\cdot573 \quad -0\cdot008 \end{cases}$$

If, however, we substitute the values of ΔS and Δσ first used in them, we have for the seconds of contact the three values $31^s\cdot6$, $38^s\cdot7$, $32^s\cdot3$, whose arithmetical mean is $34^s\cdot1$. With these assumptions regarding the diameters the weighted mean equation (p. 43) gives for contact $16^h\ 28^m\ 34^s\cdot0$.

The observed contact at Ingress was at $12^h\ 42^m\ 30^s$, and at Egress at $16^h\ 28^m\ 40^s$, the former being eight seconds earlier, while the latter is six seconds later, than the values from cusps. These intervals are such as would be due to a larger semi-diameter of the Sun for visible contacts than for those deduced from the cusps of about a quarter of a second of space.

Comparison of Observed Contacts with Measures of the Distance of the Planet from the Limb.

In making these comparisons it is necessary to know the error of the tabular places of the planet and Sun relatively to each other, and also that of the assumed parallax. I assume here that the mean solar parallax is $8''{\cdot}73$, so that the value of $\Delta\pi$ in my equations is $0''{\cdot}15$. Also the longitude of Madras having been determined by the officers of the Great Trigonometrical Survey of India, by the telegraphic method, I shall use their corrections to the assumed longitude of my Report, thus: $\Delta L = +2^s{\cdot}15$.

On the last page are given the following values for the correction of the relative places of the Sun and *Venus*, in which I introduce the above values—

$$\begin{aligned} &\Delta \text{A.R.} = +6''{\cdot}502 - 0{\cdot}071\,\Delta L - 0{\cdot}989\,.\,\Delta\Pi = +6''{\cdot}50, \\ &\Delta \text{N.P.D.} = -2{\cdot}247 - 0{\cdot}017 \quad -2{\cdot}629 \quad = -1{\cdot}89. \end{aligned}$$

These have been deduced from Colonel Campbell's observations with an Altazimuth. I also learn from Colonel Tupman that a discussion of the measures of the American photographs has given the following values:—

$$\Delta \text{R.A.} = +4''{\cdot}83; \text{ and } \Delta \text{N.P.D.} = -2''{\cdot}89.$$

From the equations of condition in my Report, I get, after substituting the values of ΔL and $\Delta\Pi$,

At Ingress	From contact	$\Delta S - \Delta\sigma$	$= -7''{\cdot}56 + 0{\cdot}6418\,\Delta \text{A.R.} - 0{\cdot}7183\,\Delta \text{N.P.D.}$
	„ measures	$\Delta S - 0{\cdot}833\Delta\sigma$	$= -6{\cdot}41 + 0{\cdot}5865\,\Delta \text{A.R.} - 0{\cdot}7710\,\Delta \text{N.P.D.}$
At Egress	„ measures	$\Delta S - \Delta\sigma$	$= -2{\cdot}70 - 0{\cdot}1744\,\Delta \text{A.R.} - 0{\cdot}9817\,\Delta \text{N.P.D.}$
	„ contact	$\Delta S - \Delta\sigma$	$= -2{\cdot}81 - 0{\cdot}2557\,\Delta \text{A.R.} - 0{\cdot}9610\,\Delta \text{N.P.D.}$

Confining our attention at present to the contact equations, I substituted first the Roorkee corrections to the tables and then the American, calling the results R and A. Thus

		R.	A.
At Ingress	$\Delta S - \Delta\sigma =$	$-2''{\cdot}03$	$-2''{\cdot}37$,
Egress		$-2{\cdot}65$	$-1{\cdot}26$.

These values can be made identical by values of the corrections between the Roorkee and American results.

Assuming

$$\Delta \text{A.R.} = +5''\cdot90; \qquad \Delta \text{N.P.D.} = -2''\cdot25,$$

we have

$$\Delta S - \Delta\sigma = -2''\cdot15$$

in both cases.

If ΔS be $-1''\cdot85$, then $\Delta\sigma$ would be $+0''\cdot30$, much as deduced from the cusps; but it must be remembered that if ΔS here be $-1''\cdot85$, then, as I have shown before, the cusp times require for that class of observation $\Delta S = -2''\cdot10$.

If the last values of the corrections of tables be now substituted in the equations from measures, we have

$$\begin{aligned} \Delta S - 0\cdot833\,\Delta\sigma \text{ (Ingress)} &= -1''\cdot22, \\ \Delta S - \Delta\sigma \quad\ \text{(Egress)} &= -1\cdot51. \end{aligned}$$

If we assume $\Delta\sigma = +0\cdot29$, as found from cusp measures, we shall have the mean value of $\Delta S - \Delta\sigma = 1''\cdot39$, which is three-quarters of a second greater than from the contacts, and a change in $\Delta\sigma$ would not sensibly alter this.

Thus the cusp measures point to a value of $\Delta\sigma$ of $+0''\cdot29$, and the contact times then derived from them require that the centres of Sun and planet should be a quarter of a second nearer than at the moment of visible contact. On the other hand, the measures of the distance of limbs of Sun and *Venus* show that the solar limb seemed to extend three-quarters of a second beyond the place where the visible internal contact was seen.

With these adjustments of the diameters and errors of the tabular places which fall between those determined at Roorkee and by the American parties the Roorkee contacts and cusp equations of condition are satisfied, and the residual errors in the distances from the limb are very small, the discordance between the Ingress and Egress measures being only about $0''\cdot36$.

Calcutta:
1882, *March* 25.

Note on the Illumination of Micrometers. By A. A. Common, Esq.

The satisfactory illumination of the wires of the micrometer of the astronomical telescope has hitherto been a difficult and troublesome affair. Certainly it is not that much light is wanted, but what little is needed should be in the right place and in one constant direction.

I have tried many different ways experimentally, but in practice always the only thing that answered well was the oil

lamp, mounted in the same way that is so well described by Mr. Burnham in the March number of these *Notices*. The first lamp made on this plan, some three or four years ago, was attached to the micrometer direct (I have brought this to show how in certain positions the smoke from the lamp comes on to the micrometer or into the observer's eye). This plan was altered to that shown in the account of my 3-foot Reflector in the *Memoirs*, vol. xlvi.—that is, attached to the position circle, and with means of varying the intensity and colour of the light —a necessary thing. This with an improved micrometer makes a very serviceable instrument.

Incandescent platinum wire was tried ; and this, from the fact that it can be used anywhere and requires, therefore, no reflector, gave hope, but the wire when heated high enough to give a good light is apt to burn on the slightest increase of current.

Vacuum tubes were tried, but the experiment of one shock on the eye from the small coil used was sufficient.

Lately I have tried the small incandescent carbon lamps that are now produced commercially, and can be readily obtained. These are made as small as five-candle power, and as this is quite enough for any purpose, and they can be used at any required power under this, and will last a long time, they seem to be the very things for the work. These lamps are now very well known, and their advantages for this special work are very great. The only thing that may be a trouble is the production of the current of electricity. Where a large number could be used about an observatory, the use of a dynamo-machine driven by power would be best, but in ordinary cases, where the great difficulty is only with the micrometer, a small battery of, say, five bichromate cells will do well, and by a cord worked by the foot or any other means, the light can be produced or varied by lowering the plates in the solutions. The wires may be led anywhere and the connection with the micrometer made either by flexible wire or by insulated rings and contact springs, in a way that will naturally be apparent to one.

From the trials I have made I consider it well worth trying by anyone who is not satisfied with the old oil lamp.

1882, *May* 12.

On the Solar Spots of April and May 1882. By the Rev. F. Howlett.

The great solar spot which, according to the observations of the Astronomer Royal and Mr. Whipple of the Kew Observatory, first made its appearance on the visible disk in the Sun's southern hemisphere on April 13, 1882, was in every way worthy of the Sun-spot maximum of the present epoch, accompanied as it was with remarkable magnetic storms, which com-

menced on the 14th, but which more especially manifested themselves, as I was informed at Kew, on the night of the 16th till about 8 P.M. on the 17th, after which they diminished until about 3^h 20^m of the 20th of the same month, when they were again very active.

Strong Earth currents considerably interfered at times with telegraphic communication, especially on the 17th aforesaid, not only in this country, but at Brussels, and doubtless many other parts of the world.

At Alton I was informed by the Post Office authorities that the dial plate of their telegraphic apparatus had to be turned round many degrees before the needles were free to oscillate. As regards the magnitude of the largest spot, on April 19, at 3^h 30^m P.M. this had a length of about 2′ 15″, with a mean breadth of about 1′ 15″, and which, making due allowance for irregularities of contour, implies a superficial area of not less than 2,050 millions of square miles.

Another large pair of spots, which preceded the former one just described, were each about 65″ in mean length and breadth, possessing, therefore, a joint area of about 855 million square miles, whilst the remaining small spots contained about 730 millions; making a total disruption of the solar photosphere of not less than 3,644 millions of square miles—a condition of things which I have not seen equalled since the still more wonderful outbursts of February 1870, when a group was on the disk subtending 6′ of arc, or of September 21 of the same year, when the total area occupied by the various groups amounted at one time to not less than 5,000 million square miles. I possess a superb photograph of the disk of that date 2 feet in diameter.

I would observe also that the forms assumed by the great spot of April of the present year not a little resembled those of the memorable outburst of August and September 1859, which were distinguished also by very remarkable and repeated magnetic storms. The principal spot of April of the present year was characterised, as then also, by a very peculiar whirling or cyclonic-looking disposition, especially during the earlier stages of its development, and was accompanied, as was the case in August 1859, by a large pair of associated spots on another part of the disk, which, however, *followed* the principal group in 1859, but *preceded* it in April 1882.

Some fine and interesting spots have been also visible during the present month of May, one of which, making due allowance for the time required by a synodic revolution of a spot, would appear to be the diminished representative of that of April 13; but of this I am not sure.

On May 8th a fine and conspicuously round spot was to be seen nearly in the middle of its passage across the Sun's northern hemisphere, and having a mean diameter of about 46″. It is not often that neatly-rounded spots of such magnitude are seen on the disk.

Finally, during the whole nearly of April and May of the present year faculæ of unwonted extent and brilliancy have been visible on the disk, being plainly traceable sometimes to a distance of from five to six minutes of arc from the limb, instead of from about three to four minutes only, which latter are about the limits wherein they are more generally to be seen. Is it not therefore probable that simultaneously with greatly increased solar activity, as indicated by the spots, the faculæ are also upheaving the solar photosphere in mountainous billows of unusual altitude?

The Great Sun-spots of April. By Henry Pratt, Esq.

Having secured a series of photographs of the grand display of spots on the Sun's southern hemisphere, I send copies of some of them with this, although not as good as I desired.

By measures taken from the negative of April 18, 2 P.M., it appears that the total length of the group containing the grandest spot extended to a distance of about 3′, while the diagonals of the principal spot (which formed a rude square) equalled 2′ 7″, or about 59,000 miles, and 1′ 57″, about 52,000 miles, the average length of its sides being 1′ 35″, about 43,000 miles. The total length of the other group reached 2′ 52″, about 76,000 miles.

From a comparison between the negative taken on April 20, 9.20 A.M., and that last referred to, it appears that the great spot had not only considerably altered in form (so that the Maltese cross-like markings had disappeared), but that its length had diminished, whilst its breadth had remained nearly constant. The total length of the last-described group had increased, while an enormous development had taken place between the two principal spots, which had previously been separated by a space almost free from penumbra.

18 *Preston St., Brighton.*

On the Nebula near Merope. By T. W. Backhouse, Esq.

Mr. Burnham having expressed a doubt as to the existence of this nebula, I looked for it on February 13, about 10.15 P.M., with my $4\frac{1}{4}$-in. Refractor, and a power of 38. I had sometimes looked for it before, but never carefully, and had never seen it. In order that I might be unbiassed, I avoided looking at the descriptions of it in the *Monthly Notices* previous to looking for it. I did not even know which star was *Merope*. I soon found the nebula, though to see it well it was necessary to have

Merope out of the field. It was very faint, and the only definite feature was the *f* edge, which, however, was quite plain. I carefully noticed its position among the stars, and afterwards looked at the *Monthly Notices*, vol. xl., and found that its position was almost exactly the same as in Tempel's drawing, p. 622. Taking the squares in that drawing to be 15′ in length, the two brightish stars in it at about 5′ and 10′ off *Merope* were upon the *f* edge; while the bright star about 16′ off *Merope* was outside it, rather further off it than in Tempel's sketch, only I suspected that the nebula came up to that star, but more faintly.

Mr. Common's drawing, page 376, appears to be very rough, or perhaps he has confounded two stars, for his principal nebula does not touch the nebula as I saw it: indeed, the sky is perfectly dark where he draws it.

On February 18 I looked for the *n* edge of the nebula, but could not detect it with any certainty, owing to the brightness of the neighbouring stars; *Electra* at least being in the field at the same time.

Sunderland:
1882, *April* 25.

Determination of the Orbit of η Cassiopeiæ. By J. B. Coit, Esq.

(*Communicated by the Astronomer Royal.*)

I have recently completed a determination of an orbit for this beautiful binary, and a comparison of the same with all the observations at my command.

Before giving my results I would offer a few suggestions concerning the work, which, to my mind, is most needed in the line of double-star observations.

There is at present a manifest tendency upon the part of many to encourage the search for new pairs, to the neglect of the old binaries of Herschel and Struve. It is undoubtedly desirable that our catalogue of multiple stars should be extended as far as possible, in order that we may investigate the law of their distribution. At the same time, however, it is of primary importance that the orbits of several binaries be determined with all possible precision, for by this means alone can we hope to discover the laws which govern their motions, and the forces that rule in these sidereal systems. To accomplish this, the computer needs multiplied observations, with all the data that can enable him to properly determine the relative weight of each measurement.

I suggest, then, that all the systematic labour possible be centred upon a definite list of binaries, representing fairly the different classes, as to period, eccentricity, &c., as already approximately determined. If this work were faithfully done, though the present generation might see but little of the fruits

of the labour, the future computer, with the data furnished by our concentrated efforts, would be enabled to determine the orbits with all needed definiteness.

The following is the orbit determined for η *Cassiopeiæ* :—

$P = 167{\cdot}4$ years.
$T = 1904{\cdot}0$ A.D.
$\lambda = 233{\cdot}1^\circ$
$\gamma = 52{\cdot}09$
$\Omega = 41{\cdot}02$
$\epsilon = 0{\cdot}622$
$a = 8''{\cdot}702$

This would give a mean distance 56·5 times our mean distance from the Sun, and a mass 6·4 times that of our Sun, if we accept the parallax as given by O. Struve, viz. $0''{\cdot}154$.

The annexed table exhibits the comparison of this orbit with the observations at hand. The computation is carried only to the first decimal place, as this seemed to be the degree of accuracy warranted by the discordant character of the observations, which is revealed as soon as they are arranged in chronological order. By tabulating the comparison with different observers many interesting results might be discovered, which we have not the space here to note. Without assuming for the above orbit absolute accuracy, it is safe to affirm that some of the observations are affected by a systematic error.

In the following table θ_c indicates the angle as computed by this orbit; θ_o the angle given by the observer, reduced to 1881·0, for those dates where the correction would be appreciable. $\theta_c - \theta_o$ presents the resulting residuals. Similarly for the distances ρ_c and ρ_o.

Mr. L. E. Holden's Observatory,
Cleveland, Ohio :
1882, *April* 12.

Observer.	No.	Epoch.	θ_c	θ_o	$\theta c - \theta o$	ρ_c	ρ_o	$\rho c - \rho o$
						″	″	″
W. Herschel	1	1779·80	—	—	—	11·1	11·1	0·0
„	2	1780·50	—	—	—	11·1	11·5	−0·4
„	3	1782·40	57°·6	61°·0	−3°·4	11·1	—	
„	4	1803·10	69·5	70 8	−1·3	11·6	—	
Struve	5	20·16	80·0	81·2	−1·2	10·9	10·7	+0·2
Hers. & South	6	21·90	81·0	82·9	−1·9	10·8	8·8	+2·0
„	7	25·78	83·7	83·2	+0·5	10·5	9·9	+0·6
Struve	8	27·21	84·6	85·7	−1·1	10·4	10·2	+0·2
Hers. & South	9	28·90	85·9	86·5	−0·6	10·3	12·0	−1·7

Observer.	No.	Epoch.	θ_c	θ_o	$\theta_c-\theta_o$	ρ_c	ρ_o	$\rho_c-\rho_o$
			°	°	°	″	″	″
Bessel	10	1830·75	87·2	86·3	+0·9	10·1	10·1	0·0
Smyth	11	30·91	87·3	87·9	−0·6	10·1	9·8	+0·3
,,	12	31·92	88·2	88·3	−0·1	10·0	9·9	+0·1
Struve	13	32·05	88·3	87·7	+0·6	10·0	9·8	+0·2
Dawes	14	32·87	89·0	88·7	+0·3	9·9	9·7	+0·2
Smyth	15	33·74	89·6	89·0	+0·6	9·9	9·9	0·0
Bessel	16	34·76	90·4	89·7	+0·7	9·8	9·8	0·0
Smyth	17	35·20	90·8	91·0	−0·2	9·7	9·7	0·0
Struve	18	35·26	90·9	91·3	−0·4	9·7	9·5	+0·2
,,	19	36·74	92·0	92·2	−0·2	9·6	9·4	+0·2
Smyth	20	36·81	92·1	92·1	0·0	9·6	9·4	+0·2
Encke	21	37·62	92·7	92·6	+0·1	9·5	9·6	−0·1
Galle	22	38·68	93·7	92·7	+1·0	9·4	9·5	−0·1
Kaiser	23	40·43	95·2	95·9	−0·7	9·2	9·0	+0·2
G. O.	24	40·44	95·2	96·5	−1·3	9·2	9·0	+0·2
O. Struve	25	41·34	96·1	98·2	−2·1	9·2	9·2	0·0
Mädler	26	41·57	96·3	96·5	−0·2	9·1	9·2	−0·1
Dawes	27	41·80	96·5	95·8	+0·7	9·1	9·3	−0·2
Mädler	28	42·39	97·0	98·4	−1·4	9·0	8·7	+0·3
Smyth	29	43·19	97·8	95·9	+1·9	9·0	9·4	−0·4
Mädler	30	44·56	99·1	100·2	−1·1	8·8	8·6	+0·2
,,	31	45·39	100·0	102·0	−2·0	8·7	8·5	+0·2
,,	32	46·67	101·3	101·2	+0·1	8·6	8·6	0·0
Smyth	33	46·73	101·3	101·6	−0·3	8·6	8·5	+0·1
D. O.	34	47·08	101·8	104·1	−2·3	8·6	8·8	−0·2
O. Struve	35	47·40	102·0	101·8	+0·2	8·5	8·5	0·0
Mädler	36	47·42	102·0	102·8	−0·8	8·5	8·3	+0·2
Miller	37	47·60	102·2	101·5	+0·7	8·5	8·6	−0·1
Mitchel	38	47·63	102·2	101·4	+0·8	8·5	8·6	−0·1
O. Struve	39	49·66	104·5	105·0	−0·5	8·3	8·3	0·0
Mädler	40	50·80	105·8	106·6	−0·8	8·2	8·0	+0·2
Jacob	41	50·87	105·9	105·6	+0·3	8·2	8·2	0·0
Mädler	42	51·76	107·0	107·0	0·0	8·1	7·7	+0·4
O. Struve	43	51·84	107·0	108·1	−1·1	8·1	8·0	+0·1
Jacob	44	51·88	107·1	106·5	+0·6	8·1	8·0	+0·1
Miller	45	51·90	107·1	107·0	+0·1	8·1	8·1	0·0
Mädler	46	52·67	108·0	108·7	−0·7	8·0	7·6	+0·4
Jacob	47	52·75	108·0	108·0	0·0	8·0	8·0	0·0
,,	48	53·13	108·5	109·1	−0·6	7·9	7·9	0·0

Observer.	No.	Epoch.	θ_c	θ_o	$\theta_c-\theta_o$	ρ_c	ρ_o	$\rho_c-\rho_o$
			°	°	°	″	″	″
Mädler	49	1853·29	108·8	110·2	−1·4	7·9	7·6	+0·3
„	50	53·90	109·5	112·8	−3·3	7·8	7·5	−0·3
Peters	51	53·93	109·5	109·7	−0·2	7·8	8·2	−0·4
Powell	52	53·94	109·5	109·5	0·0	7·8	7·6	+0·2
Jacob	53	53·98	109·6	109·8	−0·2	7·8	8·0	−0·2
Dawes	54	54·00	109·6	109·6	0·0	7·8	7·9	−0·1
Smyth	55	54·17	109·7	110·6	−0·9	7·8	7·7	+0·1
O. Struve	56	54·56	110·3	112·0	−1·7	7·8	8·0	−0·2
Dembowski	57	54·77	110·6	111·2	−0·6	7·8	7·9	−0·1
Mädler	58	54·80	110·6	111·8	−1·2	7·7	7·6	+0·1
Powell	59	54·94	110·8	111·5	−0·7	7·7	7·5	+0·2
Morton	60	54·95	110·8	111·0	−0·2	7·7	8·1	−0·4
Dembowski	61	55·08	111·0	112·8	−1·8	7·7	7·8	−0·1
Winnecke	62	55·25	111·2	110·9	+0·3	7·7	7·9	−0·2
Mädler	63	55·51	111·6	112·0	−0·4	7·7	7·6	+0·1
Secchi	64	55·79	111·9	112·2	−0·3	7·6	7·9	−0·3
Mädler	65	55·87	112·0	111·0	+1·0	7·6	7·8	−0·2
Powell	66	55·92	112·1	112·5	−0·4	7·6	7·6	0·0
Morton	67	55·96	112·1	112·4	−0·3	7·6	7·8	−0·2
Luther	68	56·57	112·9	117·5	−4·6	7·5	8·3	−0·8
Dembowski	69	56·58	113·0	114·2	−1·2	7·5	7·4	+0·1
„	70	57·11	113·7	114·5	−0·8	7·5	7·3	+0·2
Secchi	71	57·15	113·8	112·8	+1·0	7·5	7·9	−0·4
O. Struve	72	57·22	113·8	114·1	−0·3	7·5	7·6	−0·1
Dembowski	73	57·82	114·6	115·9	−1·3	7·4	7·2	+0·2
„	74	58·46	115·6	115·8	−0·2	7·4	7·3	+0·1
Mädler	75	58·52	115·7	114·3	+1·4	7·4	7·1	+0·3
„	76	59·26	116·7	115·7	+1·0	7·3	7·0	+0·3
Powell	77	59·72	117·4	116·6	+0·8	7·3	7·0	+0·3
Morton	78	59·94	117·7	117·3	+0·4	7·2	7·1	+0·1
O. Struve	79	60·68	118·8	119·8	−1·0	7·1	7·2	−0·1
Powell	80	60·97	119·3	118·3	+1·0	7·1	7·0	+0·1
Auwers	81	61·58	120·2	119·8	+0·4	7·1	7·4	−0·3
Main	82	61·82	120·6	118·1	+2·5	7·0	6·4	+0·6
Mädler	83	61·91	120·7	119·0	+1·7	7·0	7·0	0·0
Powell	84	61·95	120·7	120·6	+0·1	7·0	6·7	+0·3
Dembowski	85	62·74	122·0	121·3	+0·7	6·9	7·0	−0·1
Romberg	86	62·86	122·2	119·1	+3·1	6·9	7·0	−0·1
„	87	62·90	122·3	121·7	+0·6	6·9	7·3	−0·4
„	88	63·04	122·5	122·9	−0·4	6·9	6·9	0·0

Observer.	No.	Epoch.	θ_c	θ_o	$\theta c - \theta o$	ρ_c	ρ_o	$\rho c - \rho o$
			°	°	°	″	″	″
Romberg	89	1863·06	122·5	122·5	0·0	6·9	6·9	0·0
,,	90	63·12	122·6	121·0	+1·6	6·9	7·0	−0·1
Luther	91	63·18	122·7	123·6	−0·9	6·9	7·1	−0·2
Dembowski	92	63·48	123·2	122·6	+0·6	6·8	6·9	−0·1
,,	93	64·10	124·3	124·5	−0·2	6·8	6·8	0·0
,,	94	64·71	125·2	124·6	+0·6	6·7	6·8	−0·1
,,	95	65·51	126·7	126·3	+0·4	6·6	6·7	−0·1
Knott	96	65·69	126·9	125·3	+1·6	6·6	6·7	−0·1
,,	97	65·69	126·9	126·7	+0·2	6·6	6·7	−0·1
,,	98	65·70	126·9	125·2	+1·7	6·6	6·8	−0·2
Talmage	99	65·73	126·9	123·9	+3·0	6·6	6·4	+0·2
O. Struve	100	66·22	128·1	132·6	−4·5	6·6	6·4	+0·2
Talmage	101	66·63	128·7	124·6	+4·1	6·5	6·4	+0·1
Secchi	102	66·86	129·0	127·7	+1·3	6·5	6·8	−0·3
Dembowski	103	67·16	129·7	129·3	+0·4	6·5	6·6	−0·1
Main	104	67·65	130·4	129·9	+0·5	6·4	6·3	+0.1
Dunér	105	68·37	131·7	131·8	−0·1	6·4	6·3	+0·1
O. Struve	106	68·53	132·1	132·9	−0·8	6·4	6·4	0·0
Dembowski	107	68·55	132·1	132·4	−0·3	6·4	6·3	+0·1
Brünnow	108	68·84	132·8	131·5	+1·3	6·3	6·3	0·0
Talmage	109	68·89	132·8	124·3	+8·5	6·3	6·2	+0·1
Main	110	69·67	134·3	132·4	+1·9	6·3	6·1	+0·2
Dembowski	111	69·68	134·3	134·1	+0·2	6·3	6·2	+0·1
Talmage	112	69·72	134·3	124·8	+9·5	6·3	6·6	−0·3
Dunér	113	69·93	134·7	135·2	−0·5	6·2	6·1	+0·1
O. Struve	114	70·18	135·3	136·2	−0·9	6·2	6·3	−0·1
Dembowski	115	70·52	136·0	135·4	+0·6	6·2	6·2	0·0
Gledhill	116	70·65	136·3	135·7	+0·6	6·2	6·1	+0·1
,,	117	70·70	136·3	138·8	−2·5	6·2	6·1	+0·1
,,	118	70·80	136·5	136·0	+0·5	6·1	6·0	+0·1
Dembowski	119	71·56	138·1	137·5	+0·6	6·1	6·1	0·0
Gledhill	120	71·60	138·3	137·6	+0·7	6·1	6·1	0·0
,,	121	71·80	138·7	138·3	+0·4	6·1	6·0	+0·1
Wilson & Seab.	122	71·93	139·0	140·9	−1·9	6·0	—	
,,	123	72·01	139·2	—		6·0	6·0	0·0
O. Struve	124	72·18	139·5	140·8	−1·3	6·0	5·9	−0·1
Dunér	125	72·50	140·1	140·5	−0·4	6·0	6·6	−0·6
Dembowski	126	72·62	140·3	139·1	+1·2	6·0	6·0	0·0
Knott	127	72·65	140·6	138·0	+2·6	6·0	6·1	−0·1
,,	128	72·65	140·6	137·7	+2·9	6·0	6·1	−0·1

Observer.	No.	Epoch.	θ_c	θ_o	$\theta_c - \theta_o$	ρ_c	ρ_o	$\rho_c - \rho_o$
Knott	129	1872·66	140°·6	138°·0	+2°·6	6″·0	6″·0	0″·0
„	130	72·66	140·6	137·7	+2·9	6·0	6·1	−0·1
Main	131	72·77	140·8	143·9	−3·1	6·0	5·9	+0·1
Talmage	132	72·86	140·9	124·4	+16·5	6·0	6·3	−0·3
Wilson & Seab.	133	73·06	141·4	142·3	−0·9	6·0	—	
Gledhill	134	73·51	142·4	143·1	−0·7	5·9	6·1	−0·2
O. Struve	135	73·53	142·4	144·6	−2·2	5·9	5·7	+0·2
Dembowski	136	73·65	142·6	140·7	+1·9	5·9	5·8	+0·1
Gledhill	137	73·73	142·9	143·8	−0·9	5·9	5·8	+0·1
„	138	73·81	143·0	144·3	−1·3	5·9	—	
Wilson & Seab.	139	73·83	143·0	144·7	−1·7	5·9	6·2	−0·3
„	140	73·83	143·0	—		5·9	6·6	−0·7
„	141	73·83	143·0	—		5·9	6·2	−0·3
Talmage	142	73·86	143·0	141·2	+1·8	5·9	5·7	+0·2
Nobile	143	73·98	143·5	143·6	−0·1	5·9	—	
Dunér	144	74·22	144·0	144·9	−0·9	5·9	5·7	+0·2
Dembowski	145	74·63	144·8	142·5	+2·3	5·8	5·8	0·0
Wilson & Seab.	146	74·90	145·6	146·0	−0·4	5·8	5·8	0·0
O. Struve	147	75·15	146·1	148·6	−2·5	5·8	5·6	+0·2
Dunér	148	75·51	146·9	146·7	+0·2	5·8	5·7	+0·1
Dembowski	149	75·60	147·2	146·2	+1·0	5·8	5·7	+0·1
Gledhill	150	75·69	147·2	147·5	−0·3	5·7	—	
Main	151	75·78	147·3	146·1	+1·2	5·7	5·8	−0·1
Doberck	152	75·93	147·8	147·8	0·0	5·7	—	
Gledhill	153	76·37	148·7	147·9	+0·8	5·7	5·6	+0·1
Talmage	154	76·86	150·0	149·3	+0·7	5·7	4·7	+1·0
Dembowski	155	76·94	150·1	149·9	+0·2	5·7	5·6	+0·1
Gledhill	156	77·41	151·4	149·9	+1·5	5·6	—	
Doberck	157	77·76	152·3	150·2	+2·1	5·6	5·7	−0·1
Wilson & Seab.	158	77·95	152·8	153·5	−0·7	5·6	5·3	+0·3
Gledhill	159	78·67	154·4	153·3	+1·1	5·6	—	
Hall	160	78·86	154·9	154·5	+0·4	5·5	5·3	+0·2
„	161	78·97	155·3	154·7	+0·6	5·5	5·4	+0·1
„	162	78·97	155·3	155·5	−0·2	5·5	5·5	0·0
„	163	79·06	155·6	156·2	−0·6	5·5	5·3	+0·2
„	164	79·06	155·6	160·8	−5·2	5·5	5·2	+0·3
„	165	79·06	155·6	156·0	−0·4	5·5	5·4	+0·1
„	166	1879·08	155·6	160·2	−4·6	5·5	5·3	+0·2